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FEASIBILITY STUDY FOR DYKE MARSH DEMONSTRATION AREA, POTOMAC RI--ETC(U)

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DREDGED MATERIAL RESEARCH PROGRAM

TECHNICAL REPORT D-[illegible]

FEASIBILITY STUDY FOR DYKE MARSH DEMONSTRATION AREA POTOMAC RIVER, VIRGINIA

by

[illegible]

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
P. O. BOX 631
VICKSBURG, MISSISSIPPI 39180

IN REPLY REFER TO: WESYV

12 November 1976

SUBJECT: Transmittal of Technical Report D-76-6

TO: All Report Recipients

1. The technical report transmitted herewith represents the results of a study to determine the engineering feasibility of developing and restoring a marsh community at Dyke Marsh using dredged material from the Potomac River estuary. This work unit (4A17) was conducted as a part of Task 4A (Marsh Development) of the Corps of Engineers' Dredged Material Research Program (DMRP). Task 4A is a part of the Habitat Development Project (HDP) of the DMRP and is concerned with the development, testing, and evaluation of the environmental, economic, and engineering feasibility of using dredged material as a substrate for marsh development.

2. Work Unit 4A17 and several other related work units deal with operational aspects of marsh development such as retaining and protective structures and guidelines for material placement for marsh creation. Other DMRP marsh-development field studies that involve the containment of fine-textured material include sites at Windmill Point, Virginia; Apalachicola Bay, Florida; and San Francisco, California.

3. Dyke Marsh, located along the Potomac River in Fairfax County, Virginia, is a vestige of a formerly large wetland area. The site is now a unit of the George Washington Memorial Parkway and is administered by the National Capital Parks, National Parks Service, for the preservation of wetland habitat. Approximately half of the original marsh was destroyed by sand and gravel mining prior to Federal ownership. The feasibility study, conducted by the DMRP with the support and cooperation of the Baltimore District, Corps of Engineers, the National Park Service, and the U. S. Fish and Wildlife Service, evaluates the potential for the restoration of marshland on an 11-hectare portion previously mined.

4. The feasibility study identifies the economic and technical constraints associated with dike construction and dredged material placement for marsh restoration at Dyke Marsh. Site specificity, preliminary containment design, availability of construction materials, identification of construction alternatives, and procedures for dredged material placement are evaluated. The Dyke Marsh study greatly contributes to the identification of the engineering constraints associated with a major marsh development site and provides basic design guidance that should be applicable to many estuarine areas.

WESYV 12 November 1976

SUBJECT: Transmittal of Technical Report D-76-6

5. The restoration of Dyke Marsh using dredged material appears technically feasible, and a detailed engineering design is currently under preparation. Construction of the project will depend on economic constraints, the findings of the environmental assessment, and the public acceptance of the design concept.

JOHN L. CANNON
Colonel, Corps of Engineers
Commander and Director

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Results of an investigation conducted to determine the engineering feasibility of using dredged material to expand an existing marshland area are presented.

Dredged material obtained from maintenance dredging operations was found suitable for use as marsh substrate and site conditions were found adequate for construction of a containment facility.

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Factors evaluated in the study include site-specific feasibility of marsh expansion using dredged material, sizing of the demonstration area to meet water-quality and storage needs, preliminary design of the containment facility, procedures for placement of dredged material, and identification of alternative construction methods, materials, and costs.

Overall feasibility of marsh expansion was demonstrated and additional investigations were recommended for the project.

EXECUTIVE SUMMARY

The objective of this report is to present the results of an investigation conducted to determine the engineering feasibility of using dredged material to expand a portion of Dyke Marsh. Dyke Marsh is a freshwater intertidal marsh located about one mile south of Alexandria, Virginia, along the west bank of the Potomac River. Beginning in the 1930's, sand and gravel have been mined from Dyke Marsh reducing its productive marshland area from 650 acres to about 380 acres.

Dredged material for this project would be obtained from maintenance dredging operations on the Potomac River just below the Woodrow Wilson Memorial Bridge, south of Alexandria. Preliminary data indicate that the sediment is suitable for use as marsh substrate and that site conditions are adequate for construction of a containment facility.

Factors concerning engineering feasibility evaluated in this study include site-specific feasibility of marsh expansion using the locally available dredged material, sizing of the demonstration area to meet water-quality and storage needs, location of the restoration project to conform with the desired plan of marshland development at Dyke Marsh, preliminary design of the containment facility, availability of construction materials, identification and investigation of possible construction alternatives, procedures for placement of dredged material to produce the desired marsh substrate elevations, and costs for different construction alternatives.

Based on the preliminary engineering studies accomplished in this investigation, extension of marshland at Dyke Marsh using dredged material appears feasible. Containment facilities can be constructed at the proposed restoration site to confine the marsh substrate, and dredged material available from the Potomac River is a suitable substrate material. A combination of hydraulic fill and dragline fill is recommended for dike construction.

More detailed field and laboratory investigations of the sediment material and foundation conditions at the proposed marsh expansion site are needed for a detailed design of the project.

PREFACE

This report presents the results of a study to determine the feasibility of developing and expanding marshland using material dredged from the Potomac River, near Alexandria, Virginia. The study was conducted as Work Unit 4A17 of the Dredged Material Research Program (DMRP), for the Office, Chief of Engineers, at the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi. This work unit is a part of the Habitat Development Project (HDP), Dr. Hanley K. Smith, Manager.

The study was conducted by the Environmental Engineering Division (EED) of the Environmental Effects Laboratory (EEL) at the WES, under the general supervision of Dr. John Harrison, Chief, EEL, and Mr. A. J. Green, Chief, EED; and under the direct supervision of Mr. R. L. Montgomery, Chief, Design and Concept Development Branch, EED.

This report was written by Mr. Michael R. Palermo, EED, and Mr. Timothy W. Zeigler, Engineering Geology and Rock Mechanics Division, Soils and Pavements Laboratory, WES. Invaluable assistance was provided by Mr. Thomas R. Patin in developing the study and in coordinating study activities with other agencies. Appreciation is also expressed to Dr. Richard S. Hammerschlag, Ecological Services Laboratory, National Park Service, and Mr. Ronald Silver, U. S. Army Engineer District, Baltimore, for their assistance.

The Directors of WES during the study were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	2.54	centimetres
feet	0.3048	metres
yards	0.9144	metres
square inches	6.4516	square centimetres
square feet	0.09290304	square metres
square yards	0.8361274	square metres
acres	4046.856	square metres
cubic feet	0.02831685	cubic metres
cubic yards	0.07645549	cubic metres
pounds (mass)	0.4535924	kilograms
pounds (force) per square inch	6.894757	kilopascals
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

FEASIBILITY STUDY FOR DYKE MARSH DEMONSTRATION AREA, POTOMAC RIVER, VIRGINIA

PART I: INTRODUCTION

Site History and Characteristics

1. The area known as Dyke Marsh is located approximately one mile south of Alexandria, Virginia, along the west bank of the Potomac River as shown in Figure 1. A heavy concentration of bedload carried by Hunting Creek readily explains the existence of a marsh at this particular location. Hunting Creek enters the Potomac at this point; the velocity of the sediment-carrying stream is checked as it enters a body of comparatively quiet water and deposition occurs. This deposition creates a local rise in the gradient of the Potomac River that effectively reduces current velocity, which causes the finer fraction of sediment load to settle out over the subaqueous trap. The silts and clays provide habitat for marsh vegetation.[1]

2. In the early 1800's attempts were made to reclaim Dyke Marsh for agricultural use by construction of a dike. The area was later abandoned, and over the years an intertidal marsh was reestablished through naturally occurring processes.[2]

3. The marshland encompassed an area of approximately 650 acres in the early 1930's. Later it became economically feasible to mine sand and gravel from the area by commercial dredging. The mining operation was active from the middle 1930's through 1970 and involved destruction of approximately 270 acres of marshland. In recent years, the Dyke Marsh area has served as a disposal ground for building rubble and construction debris from the Washington metropolitan area. This activity led to construction of an access road and creation of an elevated area consisting of debris fill on the eastern edge of the marsh.

4. The remaining portion of Dyke Marsh is still a very productive wildlife area and is the only sizeable tidal marshland in the Washington metropolitan area. Over 300 species of birds have been identified at

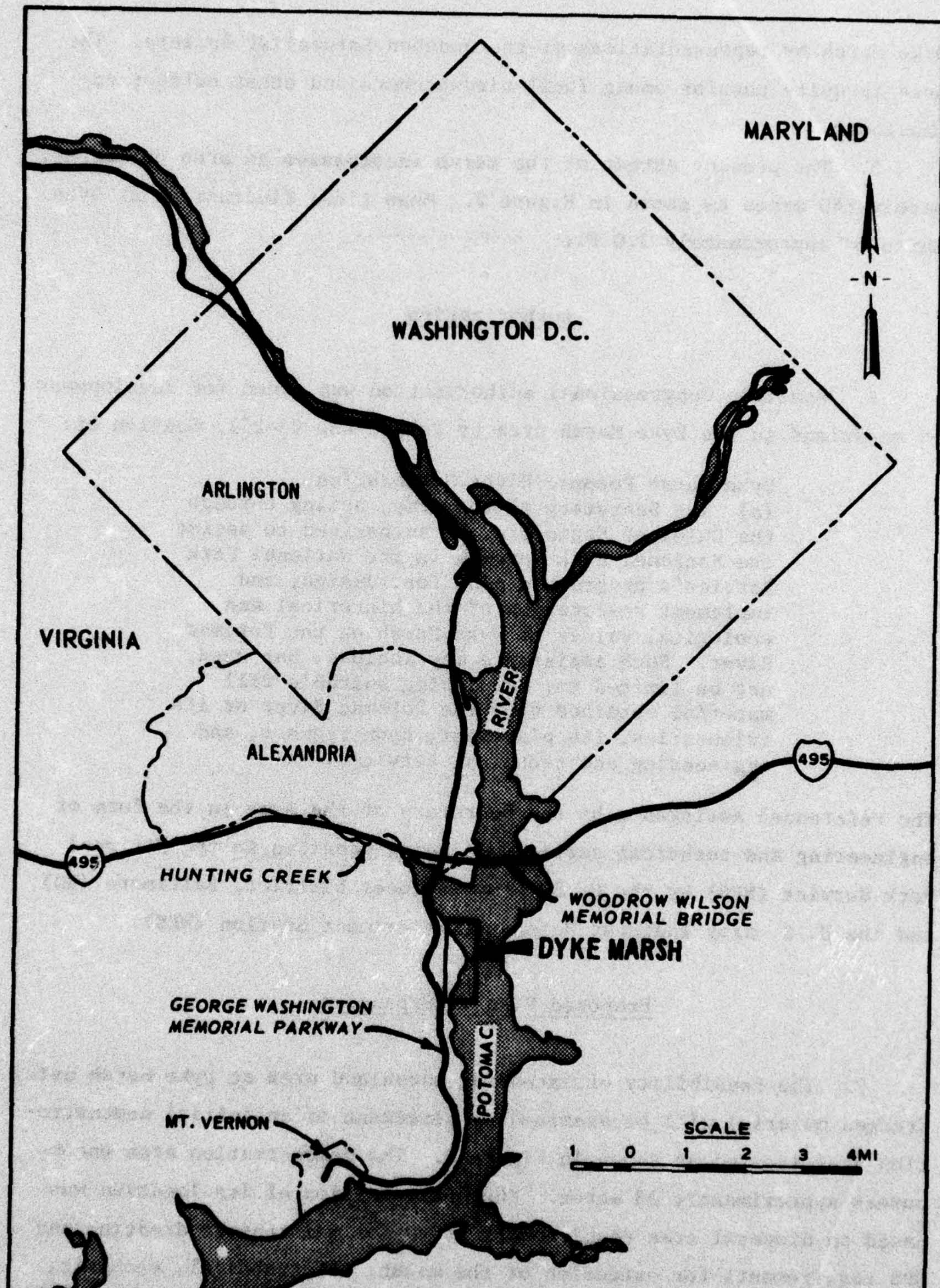


Figure 1. Location map of Dyke Marsh

Dyke Marsh by representatives of the Audubon Naturalist Society. The area is quite popular among local birdwatchers and other outdoor enthusiasts.[3]

5. The present extent of the marsh encompasses an area of approximately 240 acres as shown in Figure 2. Mean tidal fluctuation at Dyke Marsh is approximately 3.0 ft.

Authorization

6. Specific Congressional authorization was given for development of marshland in the Dyke Marsh area by Public Law 93-251, Section 86:

> Dyke Marsh Potomac River Restoration
> (a) The Secretary of the Army, acting through the Chief of Engineers, is authorized to assist the National Park Service in the National Park Service's program to plan for, design, and implement restoration of the historical and ecological values of Dyke Marsh on the Potomac River. Such assistance may include, but need not be limited to, furnishing suitable fill material obtained from the Potomac River or its tributaries, its placement, upon request, and engineering and technical services.

The referenced assistance by the Secretary of the Army in the form of engineering and technical services is being provided to the National Park Service (NPS) by the U. S. Army Engineer District, Baltimore (BD), and the U. S. Army Engineer Waterways Experiment Station (WES).

Proposed Plan of Expansion

7. The feasibility of extending marshland area at Dyke Marsh using dredged material will be examined by placement of an initial demonstration area located as shown in Figure 3. The demonstration area encompasses approximately 28 acres. The determination of its location was based on disposal area requirements of BD for maintenance dredging and NPS requirements for extension of the marsh. If technical, economic, and environmental feasibility of the expansion is shown through this

Figure 2. Aerial photo of Dyke Marsh

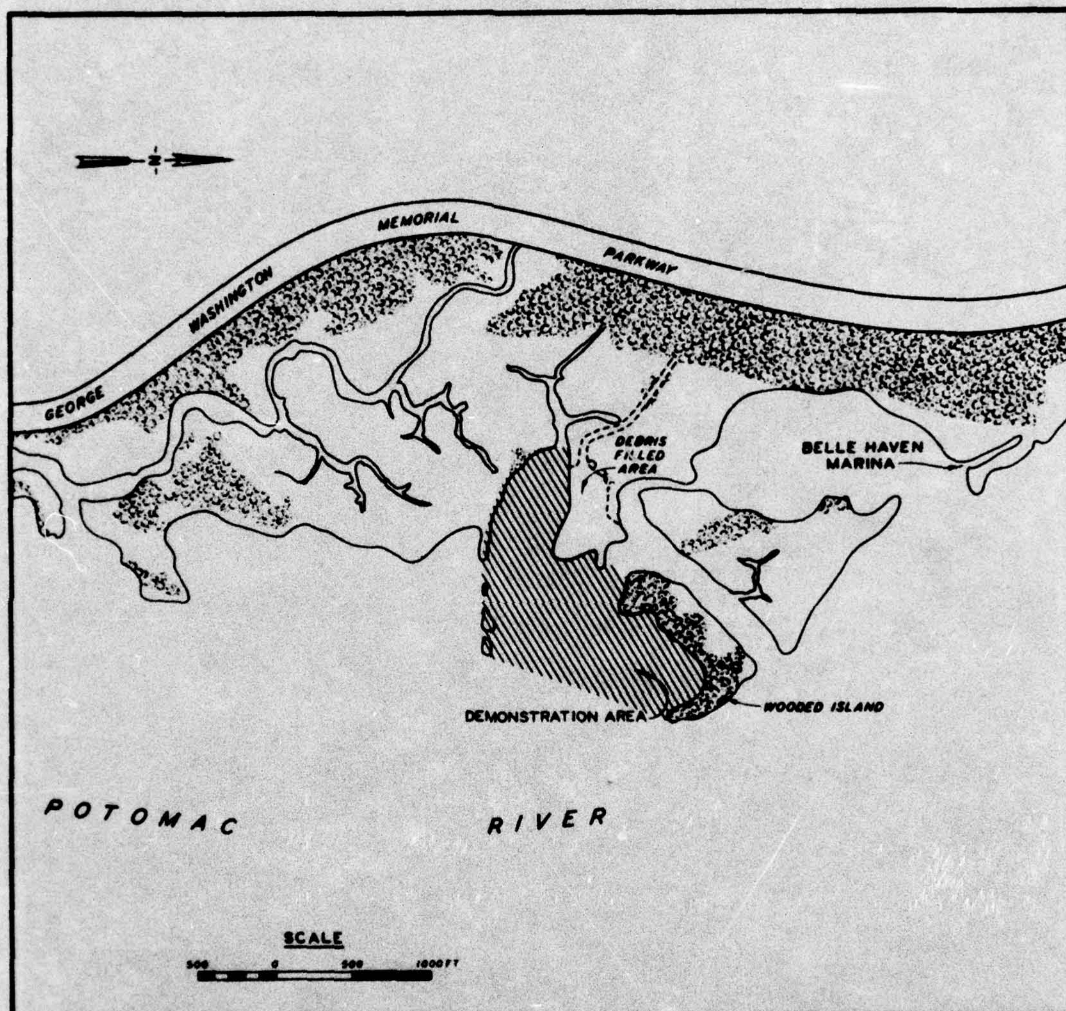


Figure 3. Location of demonstration area

initial study, design and construction of the demonstration area will proceed.

8. The general scheme for marsh expansion is shown by the conceptual views in Figure 4. A wooded island on the north limit, shallows on the south limit, and existing marsh provide a logical natural setting for additional marshland development as shown in Figure 4a. Construction of a retaining dike and outlet weirs as shown in Figure 4b will allow placement of dredged material in the demonstration area location. Ample protection of existing marshland will be provided by a temporary back dike. Dredged material will then be placed within the containment as shown in Figure 4c to elevations desirable for marsh substrate. Once material is in place, the retaining and back dikes will be lowered to elevations that will allow tidal ebb and flow and permit natural establishment of vegetation as shown in Figure 4d.

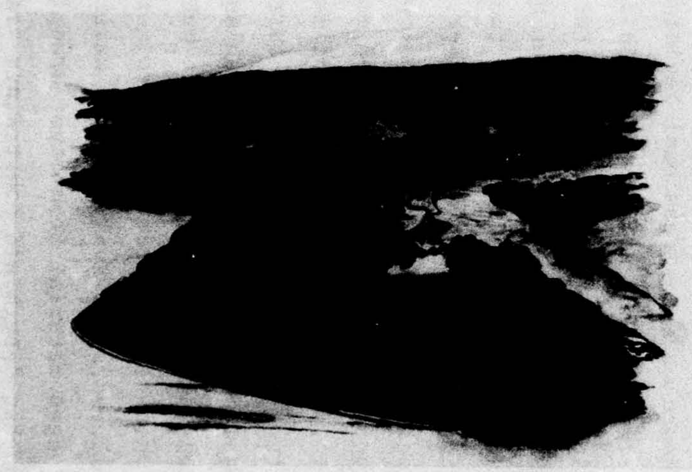
Participation and Interests of Involved Agencies

9. The NPS requested assistance from the Corps of Engineers in accordance with Congressional legislation to restore Dyke Marsh and the authorization for assistance by the Secretary of the Army. Subsequent coordination and mutual interests resulted in a cooperative effort among the NPS, BD, and WES. Retention of Dyke Marsh as a productive wildlife habitat is of primary interest to the NPS. The current expansion effort will conform to this overall concept. The NPS is coordinating the proposed project with environmental awareness groups and is the lead agency for preparation of required environmental assessment.

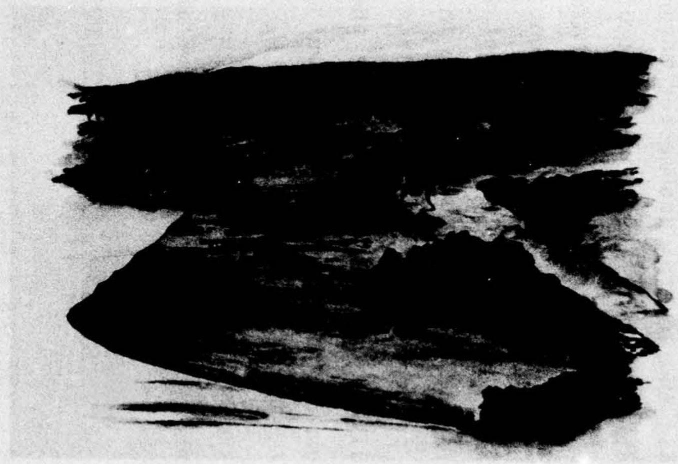
10. The planned expansion of marshland at Dyke Marsh provides the BD with a viable alternative for current and future dredged material disposal needs. Creation of marshland will provide a productive use of dredged material and will promote public acceptance of dredged material as a valuable resource. This project will also provide technical and economic data for evaluation of marsh development as an alternative use of dredged material from other dredging projects within the District. The BD has determined constraints associated with the dredging operation

a. Existing conditions

b. Construction of confinement



c. Placement of dredged material



d. Completed expansion

Figure 4. General scheme for marsh expansion

and has provided necessary support, such as surveys and field inspectors, for accomplishment of this feasibility study. Input for determination of cost estimates for the various alternative construction methods was also prepared by the BD.

11. The Dyke Marsh project will provide a field demonstration site for evaluating various marsh development techniques from previous WES research under the Dredged Material Research Program (DMRP). Additionally, the project will provide input into other research efforts and more data for evaluation of marsh development as a dredged material disposal alternative.

12. The WES conducted this feasibility study and was responsible for both the field investigation and laboratory testing work. Due to the varied mutual interests and responsibilities previously mentioned, a high degree of coordination between NPS, BD, and WES was essential for successful completion of the study.

Purpose and Scope

13. The purpose of this study was to determine the technical and economic feasibility of developing and expanding marshland at Dyke Marsh using material dredged from the Potomac River navigation channel. If the project is deemed feasible, the results of this study will be used as a basis for formulation of a detailed design for the marsh expansion project.

14. The scope of this report is restricted to assessing the engineering and economic feasibility of using dredged material for marshland expansion at Dyke Marsh. Factors concerning adaptability of the area for plant and animal habitat have been established by behavior of existing marshland adjacent to the project area and other research. Specifics concerning the environmental effects of this project are addressed in a separate environmental assessment.[4]

15. This feasibility study was based on data gathered in an initial survey and, therefore, discussions are presented in a general nature. Aspects of the study were carried only to the degree necessary

to determine feasibility and to provide a basis for later more detailed studies if feasibility was demonstrated.

16. Factors concerning engineering feasibility covered by this report include the site-specific feasibility of marsh creation and expansion using dredged material, determination of the size of the containment required to meet water-quality and storage needs, preliminary design of the retaining dikes, availability of construction materials, construction alternatives, and procedures for placement of dredged material to ensure desired final elevations for marsh substrate and costs for different construction alternatives. Economic constraints associated with the required construction and placement of dredged material are also identified.

PART II: CONTAINMENT AREA SIZING

Dredging Requirements

17. The Potomac River navigation project provides for a channel 24-ft deep and 200-ft wide from the mouth of the river to Giesboro Point at Washington. One area of shoaling lies immediately below the Woodrow Wilson Memorial Bridge, south of Alexandria (Figure 5). This shoal was selected for use in the Dyke Marsh expansion project because of the convenient location and desirable properties of the material. Surveys made during 1972 indicated that significant shoaling had occurred. The results of the survey are presented in Figure 6. The BD determined from the available survey information and estimated shoaling rates that present dredging requirements in the area would be 250,000 to 300,000 cu yd.

Sediment Characteristics

Sediment sampling

18. Fourteen sediment grab samples were taken during December 1975 in the shoal area to determine the general physical and chemical properties of the sediment to be dredged. The samples were taken in 19 to 28 ft of water using an Ekman dredge. Sample locations are shown in Figure 5. Separate samples were used for physical and chemical testing. Samples for chemical analysis were refrigerated to minimize chemical changes prior to testing.

Sediment testing

19. Testing for physical and engineering properties was conducted by the WES Soils and Pavements Laboratory. The tests consisted of laboratory classifications under the Unified Soil Classification System (USCS),[5] grain-size analysis, and Atterberg limit determinations. A summary of the test results is shown in Table 1. Results of individual tests are presented in Appendix A. Test results from chemical testing are presented in the separate environmental assessment.[4]

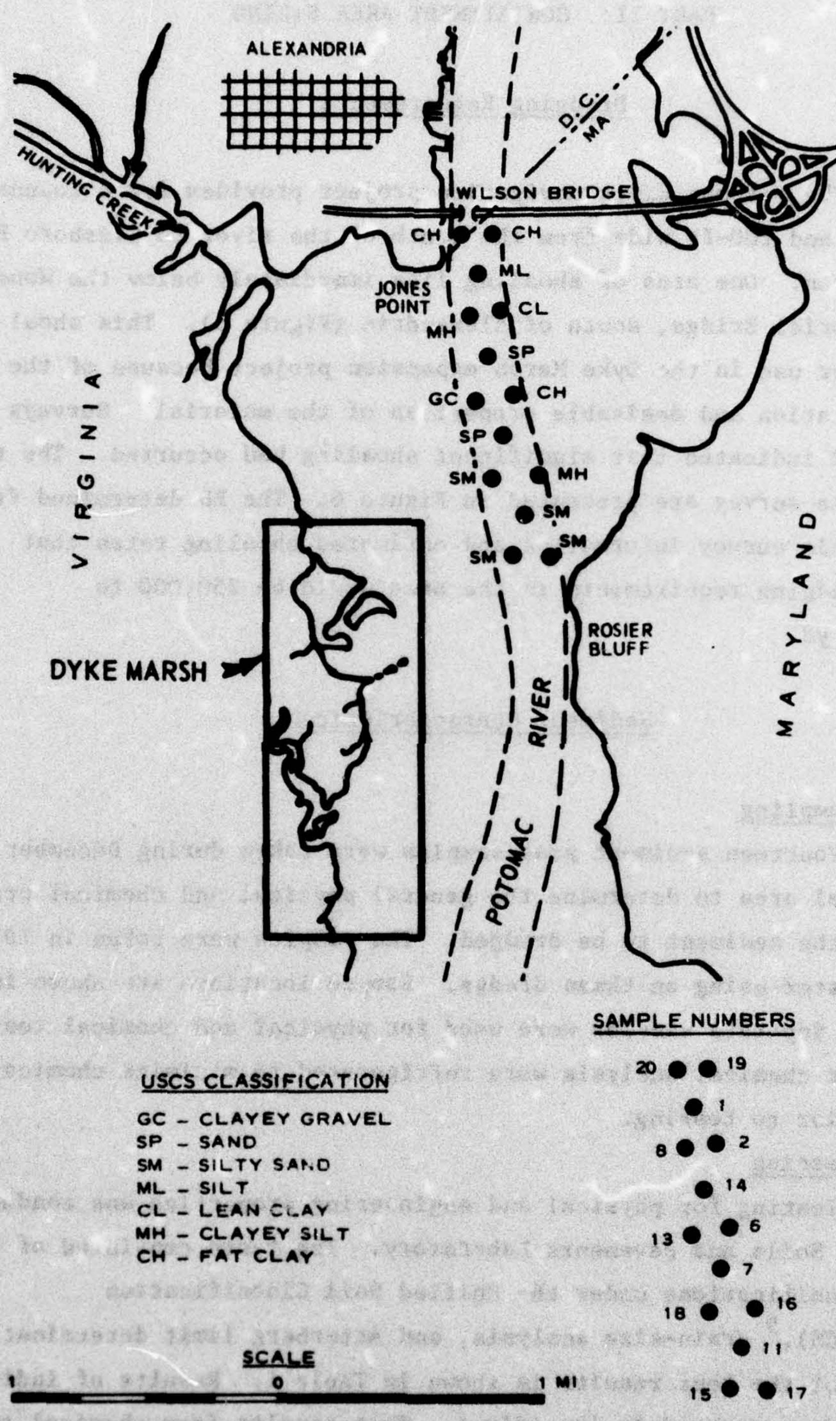


Figure 5. Sediment sampling plan in shoal location

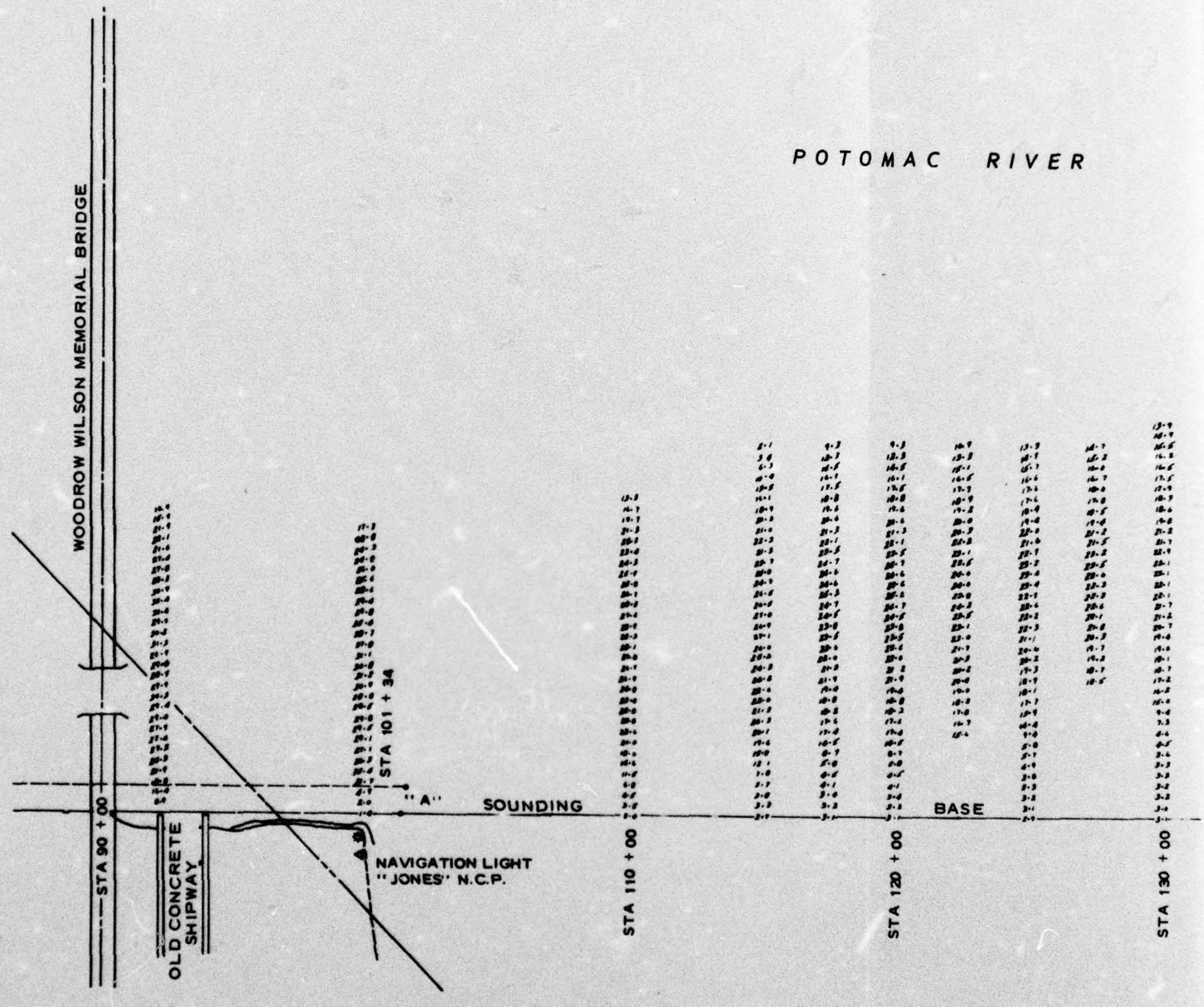
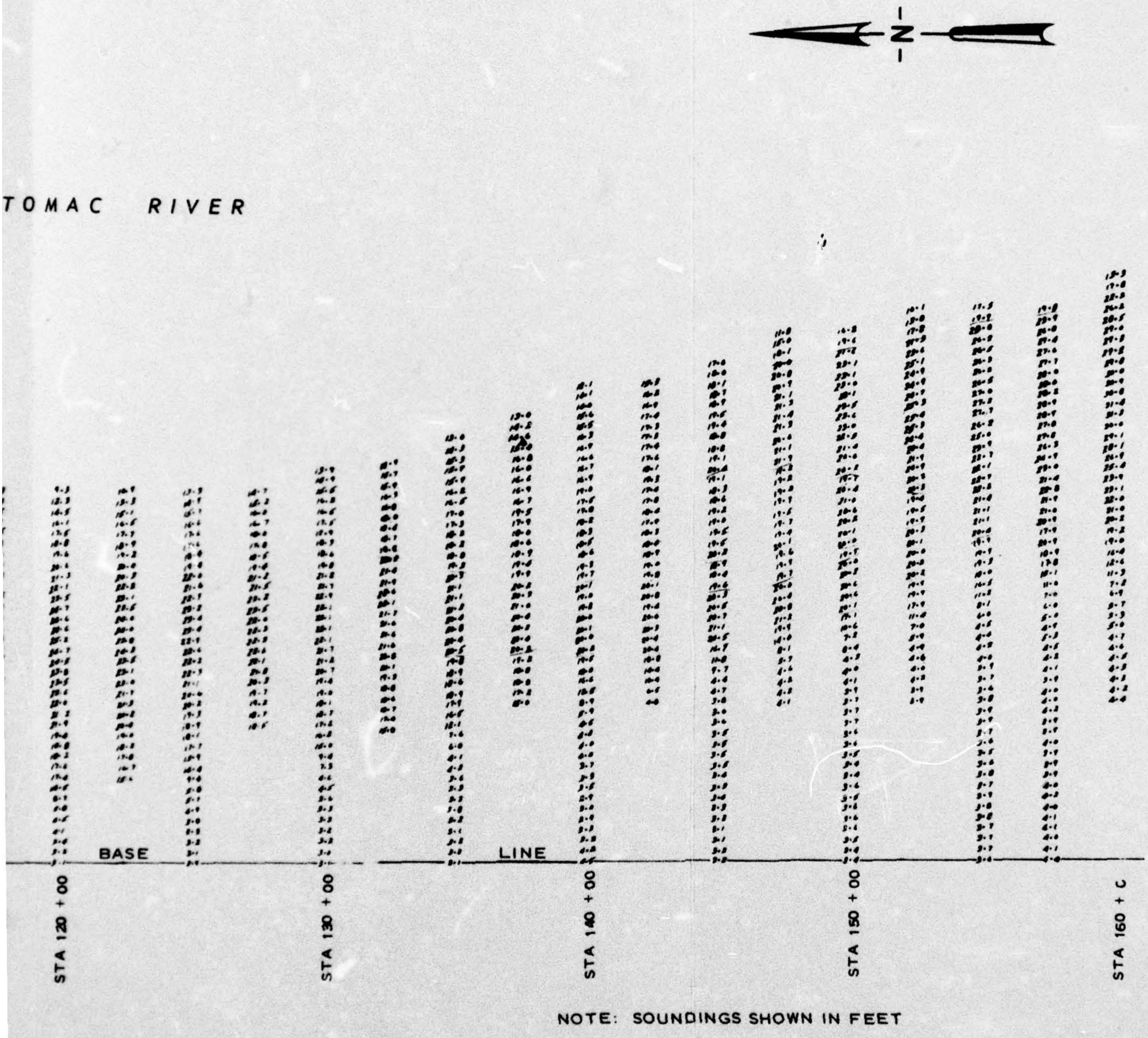


Figure 6. Shoal area survey



ure 6. Shoal area survey

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Sediment properties

20. The classifications shown in Table 1 indicate that approximately half of the sediment material, as reflected by the surface samples, is fine grained. This makes prediction of final substrate elevations for the marsh difficult and accurate measurement of sediment properties necessary for containment area sizing. In general the fine-grained sediments are located in the north portion of the shoal area adjacent to the Wilson Memorial Bridge. They consist of silts (ML and MH) and clays (CL and CH) with average values of liquid limit and plasticity index being 70 and 37, respectively. The clay material will be highly compressible in slurry form and difficult to dewater when placed in the containment facility.

21. Coarser grained material, generally found in the southern portion of the shoal, consists predominantly of silty sand (SM) although one sample classified as a clayey gravel (GC). These materials should stabilize quickly when placed in a containment area and should present no significant settlement or dewatering problems.

Containment Area Sizing

22. Containment areas are sized to provide adequate detention time for particle settling so that water-quality standards for suspended solids are met and to provide adequate storage capacity for the volume of material to be dredged. Selection of the containment site for the marsh demonstration area was based on the volume of storage capacity needed for maintenance dredging.

23. The demonstration area boundary shown in Figure 3 encompasses a total of 28 acres. Based upon pumping distance and the existing depths adjacent to Dyke Marsh, a 12-in. hydraulic pipeline dredge will be used for this project.* Therefore, the overflow rate of the effluent would be about 6 gpd/ft^2 of containment surface area. In the absence of reliable performance-loading relationships and design procedures for

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* Written communication, Baltimore District, February 1976.

designing dredged material containment areas for settling efficiencies, this loading rate was compared to those used in wastewater treatment practices. Loading rates of several hundred gpd/ft^2 are used in settling basins for wastewater treatment while maintaining an effluent with acceptable levels of suspended solids. On this basis, it appears that the loading rate for the Dyke Marsh containment facility is well below the probable maximum loading rate allowable for this size facility and the suspended solids in the effluent should be within acceptable limits. If the containment facility is operated properly to avoid short-circuiting and minimize turbulent flow, no problem is anticipated concerning unacceptable levels of solids in the effluent.

24. The potential consolidation and displacement of material were also considered in sizing the containment area. The dredged material to be placed in the containment will consist predominantly of silty sand and silts with some clays. Based on completed research concerning consolidation characteristics of dredged material, the Dyke Marsh material should stabilize within 3 to 6 months after placement in the containment area.[6] The containment area foundation consists of soft silty material that should undergo some displacement and immediate settlement after placement of dredged material. However, long-term consolidation effects in the foundation should be negligible.

25. Accounting for site topography, a final average marsh substrate elevation at mid-tidal elevation of +1.5 ft mean low water (MLW), displacement of foundation, dredged material consolidation, and surface mounding, the containment area will accommodate approximately 415,000 cu yd of placed dredged material. Shoal characteristics as indicated by grab sampling reflect the presence of some fine-grained sediments; therefore, a bulking factor of 1.50 was used in containment sizing. Therefore an estimated quantity of 275,000 cu yd of in situ material is to be dredged, commensurate with the dredging requirements cited in paragraph 17.

26. A methodology for more precise correlation between in situ volumes and containment volumes has been proposed in Reference 7, which is the report of a DMRP work unit. In the detailed design phase, the

necessary data for containment sizing using this procedure will be collected and analyses will be made to correlate the in situ and containment volumes more accurately and to verify the accuracy of the proposed methodology.

PART III: CONTAINMENT AREA CONSTRUCTION

Requirements for Containment

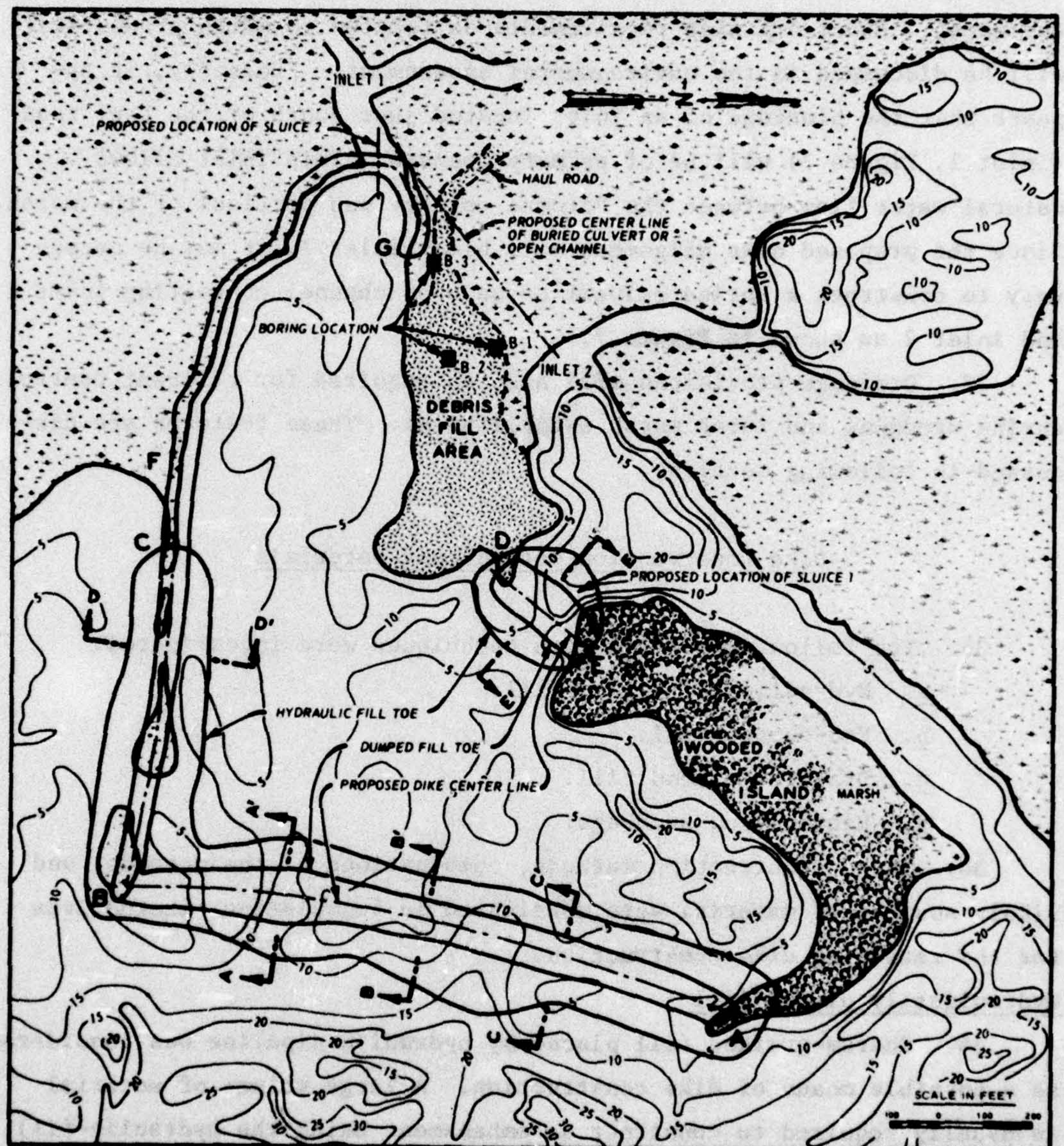
27. Grain-size analyses of sediments sampled from the shoal area (Appendix A) indicated the presence of significant quantities of fine-grained material. Consequently, a containment facility will be required to protect the existing marsh from excessive siltation during the dredging operation. The containment facility will also serve to minimize erosion of the deposits during a period of consolidation and marsh establishment.

28. The NPS recommended retaining dikes as the most desirable means for dredged material containment at Dyke Marsh. Additionally, the Environmental Protection Agency has indicated that approval of the marsh expansion would be contingent upon the use of containment dikes.

Dike alignment and elevation

29. The 28-acre demonstration area shown in Figure 3 will require construction of a retaining dike along approximately 65 percent of its perimeter. The proposed dike center line, shown in Figure 7, extends over a distance of approximately 3,400 ft. As shown in Figure 7, the dike is discontinued adjacent to the construction debris fill area and the wooded island. These two areas are elevated and presently do not support significant amounts of marsh. It is planned to allow dredged material to encroach upon the debris fill and wooded island to promote marsh development. Only minor diking will be required in these elevated areas.

30. The retaining dike will be constructed to el + 6.0 MLW along its entire length. This elevation will provide an average exterior freeboard of 3 ft at mean high water (MHW). The dike will not be designed to prevent overtopping during severe storms. The proposed freeboard will prevent excessive erosion and overtopping during periods of 1.5- to 2-ft-high waves or high tides of 5 ft. Examination of wind and tide data indicated that these conditions would occur during brief periods each year. Freeboard requirements will be reexamined in more detail in the detailed design phase.



NOTE: CONTOURS ARE IN FEET BELOW MEAN LOW WATER.

Figure 7. Containment area layout and plan of dike

Drainage requirements

31. Prior to dike construction, certain provisions may be needed to maintain as nearly as possible the present drainage conditions within the marsh. Exact drainage requirements as related to marsh productivity will be discussed in the environmental assessment. Presently, it appears that the blockage of an inlet located just south of the haul road (inlet 1, Figure 7) will be of primary concern. This inlet allows natural water flow between the Potomac estuary and portions of the marsh. Since the proposed dike alignment will block inlet 1, it may be necessary to construct a buried culvert or an open channel connecting inlet 1 and inlet 2 as shown in Figure 7.

32. Drainage provisions will also be required for effluent control during dredging and later marsh establishment. These features are discussed in following sections.

Dike Construction Methods and Materials

33. The following construction techniques were investigated:

a. Hydraulically placed fill.

b. End-dumped fill.

c. Dragline-placed fill.

d. Hand-placed sandbags.

34. These construction methods, combinations of the methods, and likely sources of material were considered in formulating alternatives for the retaining dike construction.

Hydraulically placed fill

35. Coarse-grained fill placed by hydraulic pipeline was considered as a possible means of dike construction. A large volume of material is usually required to construct an embankment using the hydraulic-fill method since materials are discharged with a large quantity of water. On land the discharge flows freely resulting in slopes as flat as 1V (vertical) on 10H (horizontal) to 1V on 30H.[8] However, when coarse-grained materials are placed in water, much steeper slopes can be obtained since the solids begin settling to the bottom immediately upon

entering the water. A coarse-grained material hydraulically placed in water is likely to yield embankment slopes ranging from 1V on 4H to 1V on 6H.

36. Hydraulic-fill placement is considered feasible for construction of dike reaches A-B, B-C, and D-E, shown in Figure 7. Hydraulic construction along dike reach F-G would be undesirable because a massive dike is not needed along the marsh border and control of material to prevent spreading over the adjacent marsh would be difficult.

37. Dike cross sections expected from hydraulic construction along dike reaches A-B, B-C, and D-E are shown in Figure 8. Above MLW embankment slopes will average 1V on 10H and below MLW slopes will average 1V on 5H. Riprap cover for slope erosion control will not be needed since wave and current energy will be dissipated on the flat slopes (see discussion in PART IV). Construction of dike reaches A-B, B-C, and D-E would require approximately 80,500, 23,500, and 15,500 cu yd of construction material, respectively. These volumes include an estimated 10 percent loss of fines during construction and assume use of relatively clean sand.

38. If silty sands are used, up to 30 percent loss of fines may occur and generation of turbidity may be expected. For this reason, use of silty sands for hydraulic construction should be kept to a minimum. Predictions of the possible magnitude of turbidity generation and its effects are addressed in the separate environmental assessment.[4]

39. A potential source of hydraulic construction material is the shoal to be dredged. Although the shoal is likely to contain large quantities of fine-grained material, grain-size analyses of river bottom sediment samples indicate that suitable coarse-grained material may be present in the central portion of the shoal (see gradation curves for sediment samples 7, 13, and 14 in Appendix A). The volume of suitable fill material located in the central portion of the shoal was estimated to be approximately 60,000 cu yd. Additional coarse-grained material could be obtained by dredging deeper than the required navigation depths. Large volumes of silty sand are also available in the shoal and could be used if required. Exploratory borings within the shoal will be necessary

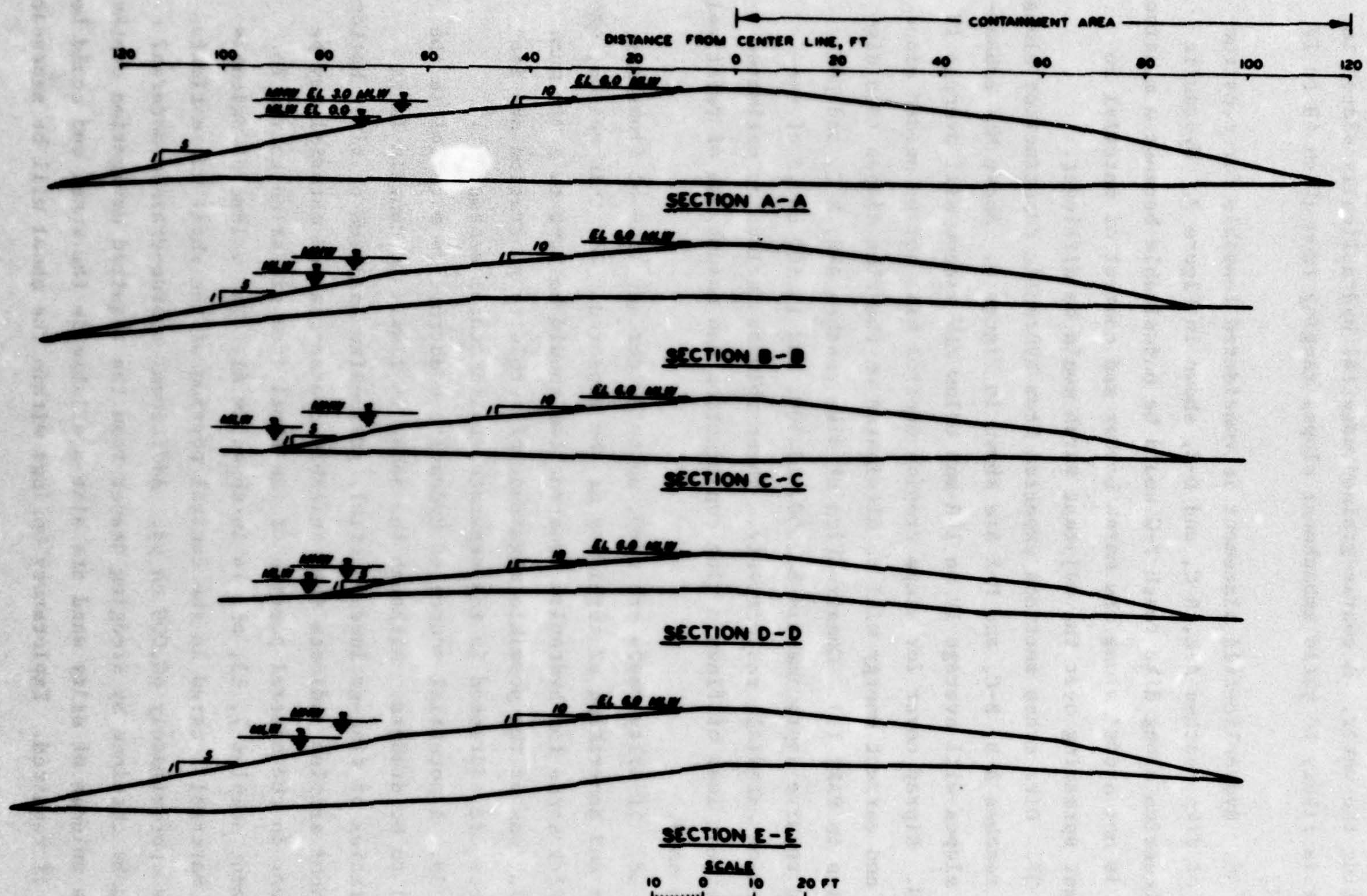


Figure 8. Hydraulic-fill cross sections (Section locations are shown in Figure 7)

to make a more reliable estimate of available volumes of coarse-grained material.

40. Other shoals within 1 or 2 miles from the site but outside of the area to be dredged should also be considered as potential sources of fill for hydraulic construction and will be investigated in the detailed design phase. However, this option would reduce the potential containment area capacity for material from the shoal requiring dredging.

41. Sediments within the containment area are also potential sources of hydraulic construction material. Unfortunately, logs of borings along the dike alignment indicate that no near surface sand deposits are present (see Figure 9). Apparently, the past commercial sand and gravel dredging operation removed most of the coarse-grained sediments. However, NPS personnel familiar with the area believe that coarse-grained materials may be present along the border of the wooded island.

42. Hydraulic construction of the retaining dike in reach A-B is illustrated in Figure 10. Construction could be conveniently initiated at a location near point A on the tip of the wooded island. The end of the dredge pipe must be supported at an elevation near the final dike grade (el + 6.0 MLW). Construction of the dike would progress from point A to point B by adding a section of pipe and supporting it on the dike crest each time the fill is brought to grade. A wye-connection and/or spreaders should be used at the pipe outlet to discharge material simultaneously on both sides of the dike center line. Spreading the fill in this manner would prevent large foundation stress concentrations and displacements during construction. Similar procedures would be used in construction of dike reaches B-C and D-E.

43. Placement operations should allow the material to take the flat 1V-on-10H slopes above MHW elevation. The flat slopes are essential for dike stability against wave and current erosion. During construction dike dimensions should be checked periodically and if necessary material added to maintain 1V-on-10H exterior slopes. This criterion can be relaxed on the interior slopes since filling the

containment area is expected to begin shortly after dike construction.

End-dumped fill

44. Retaining dikes can be constructed in water by end-dumping material from hauling trucks.[9,10] This procedure requires that embankment construction begin adjacent to land and progress outward as a haul road is established. Material dumped from trucks is pushed into the water and shaped by bulldozer. This technique has been used successfully to construct retaining dikes in water at depths of approximately 10 ft and has also been used to construct retaining dikes in marsh areas by displacing soft organic foundation materials.[10]

45. Dumped fill construction is considered feasible for all reaches of the proposed dike. Construction would begin just south of the existing haul road at point G and move along the dike alignment toward point A (see Figure 7). Dike reach D-E could be constructed simultaneously with construction progressing from point G. Typical dike cross sections with 1V-on-3H side slopes are shown in Figure 11. Although not shown in Figure 11, slope protection is required for the steeper slopes attained by end-dumped construction (see discussion in PART IV). A minimum 15-ft crest width is required to handle truck traffic. Available foundation information indicates that large foundation displacements would not occur during construction.

46. There are two potential sources of fill for construction by end-dumping. Required material can be provided by local commercial sand and gravel companies. In dike construction, the sand and gravel would be loaded at the quarry, hauled to the site, and placed along the dike alignment.

47. The other potential source of material is the debris fill area shown in Figure 7. Borings shown in Figure 12 indicate that the debris fill consists of clayey and silty sands (approximately 55 percent sand) mixed with construction rubble composed of bricks, wood, and concrete pieces.[11] More detailed information concerning the characteristics of the construction debris material will be required during the detailed design phase. For dike construction this material would be excavated, loaded on trucks, and then placed along the dike alignment. Use of the

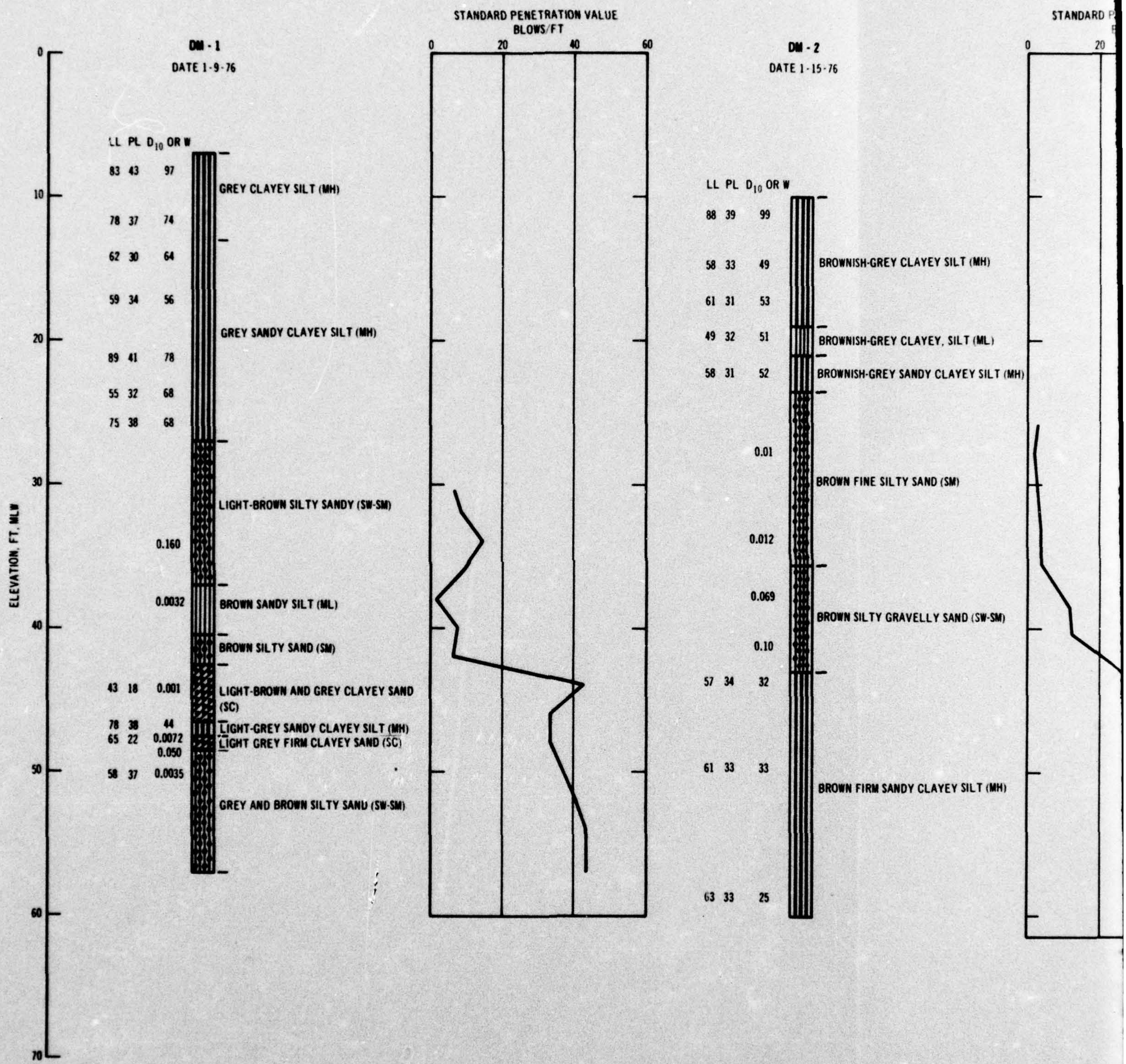
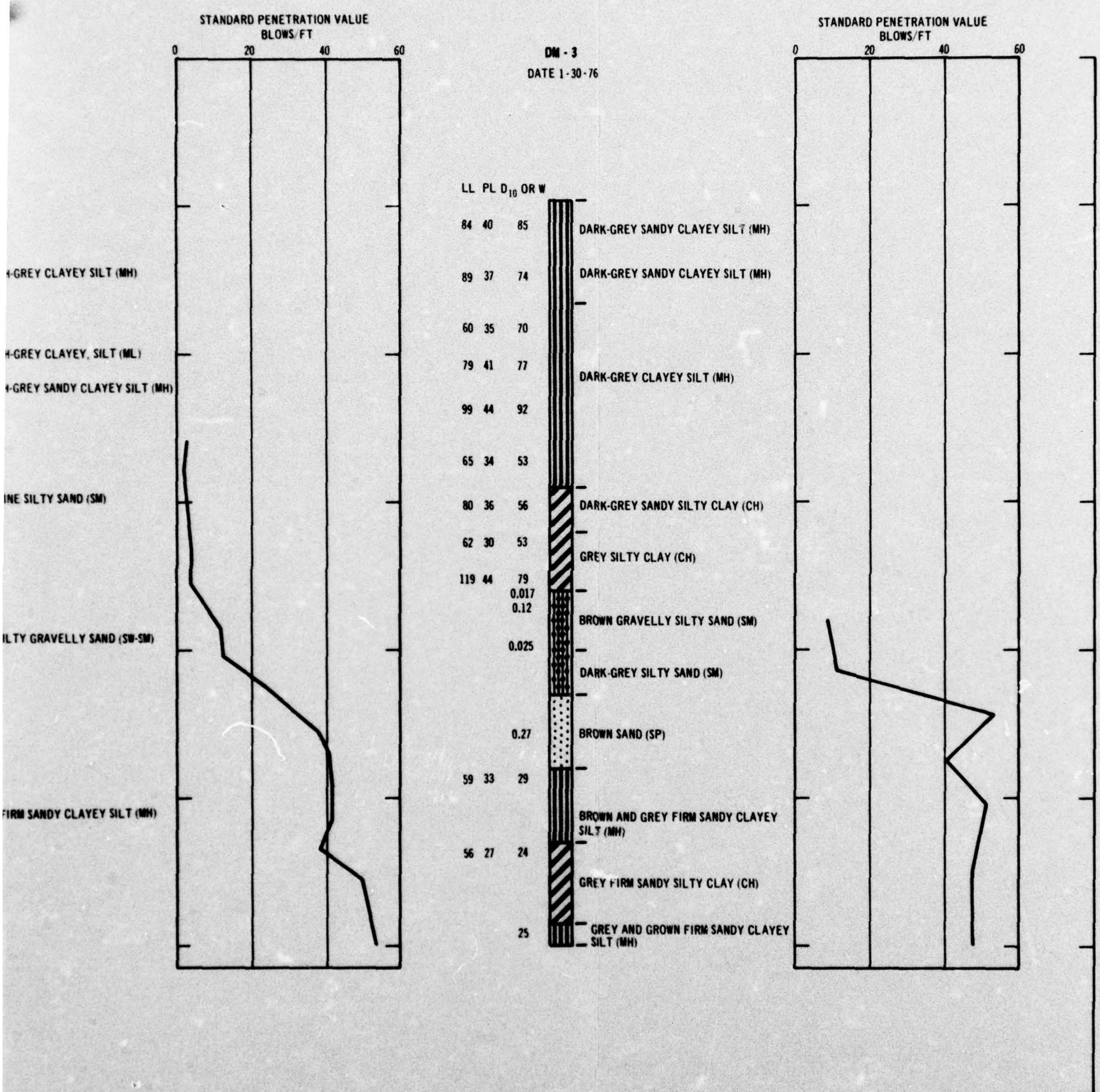


Figure 9. Foundation boring logs (see Figure 16 for



g logs (see Figure 16 for locations of borings)

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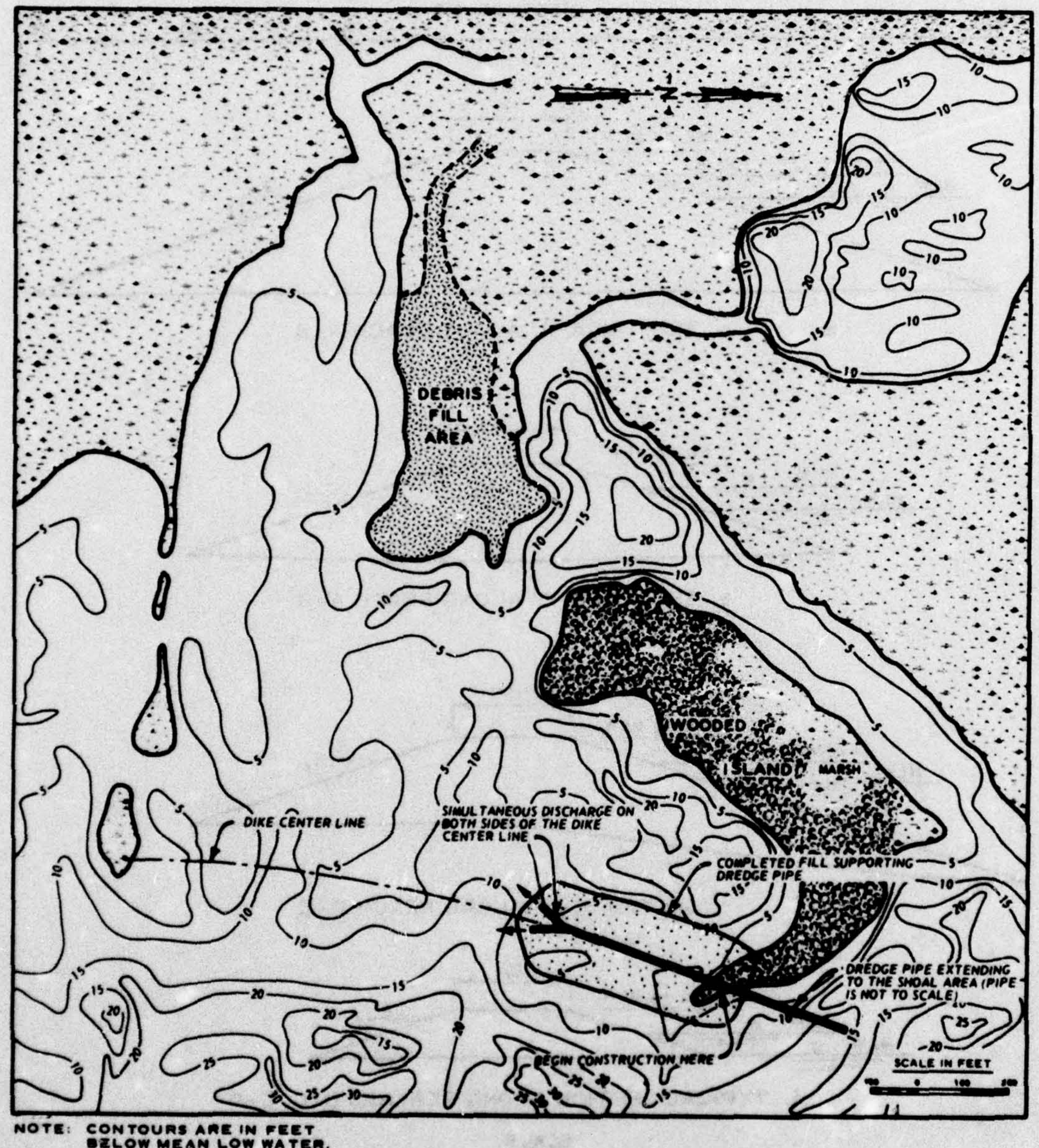


Figure 10. Hydraulic construction of retaining dike

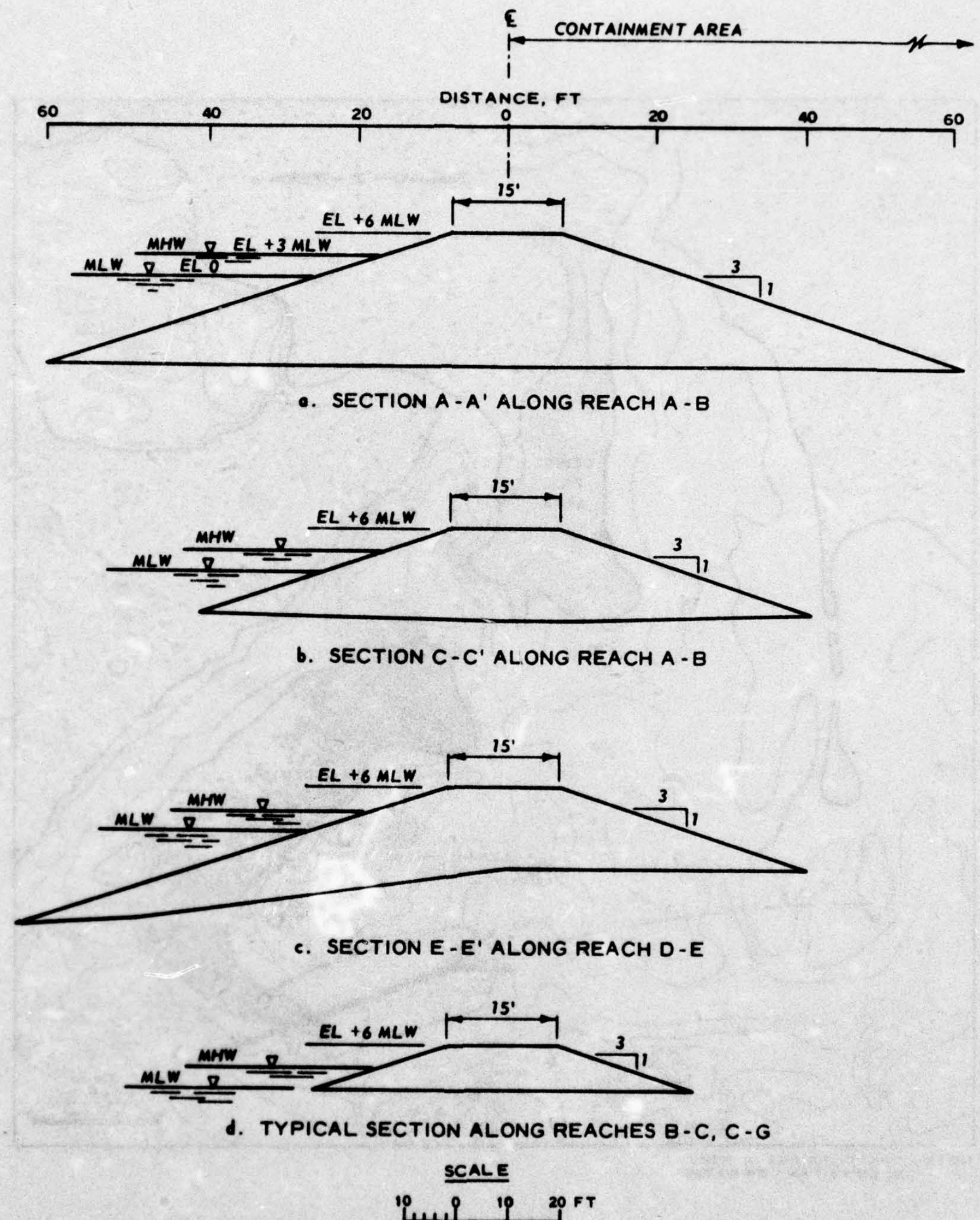


Figure 11. Cross sections for dumped fill (dike reaches and section locations are shown in Figure 7)

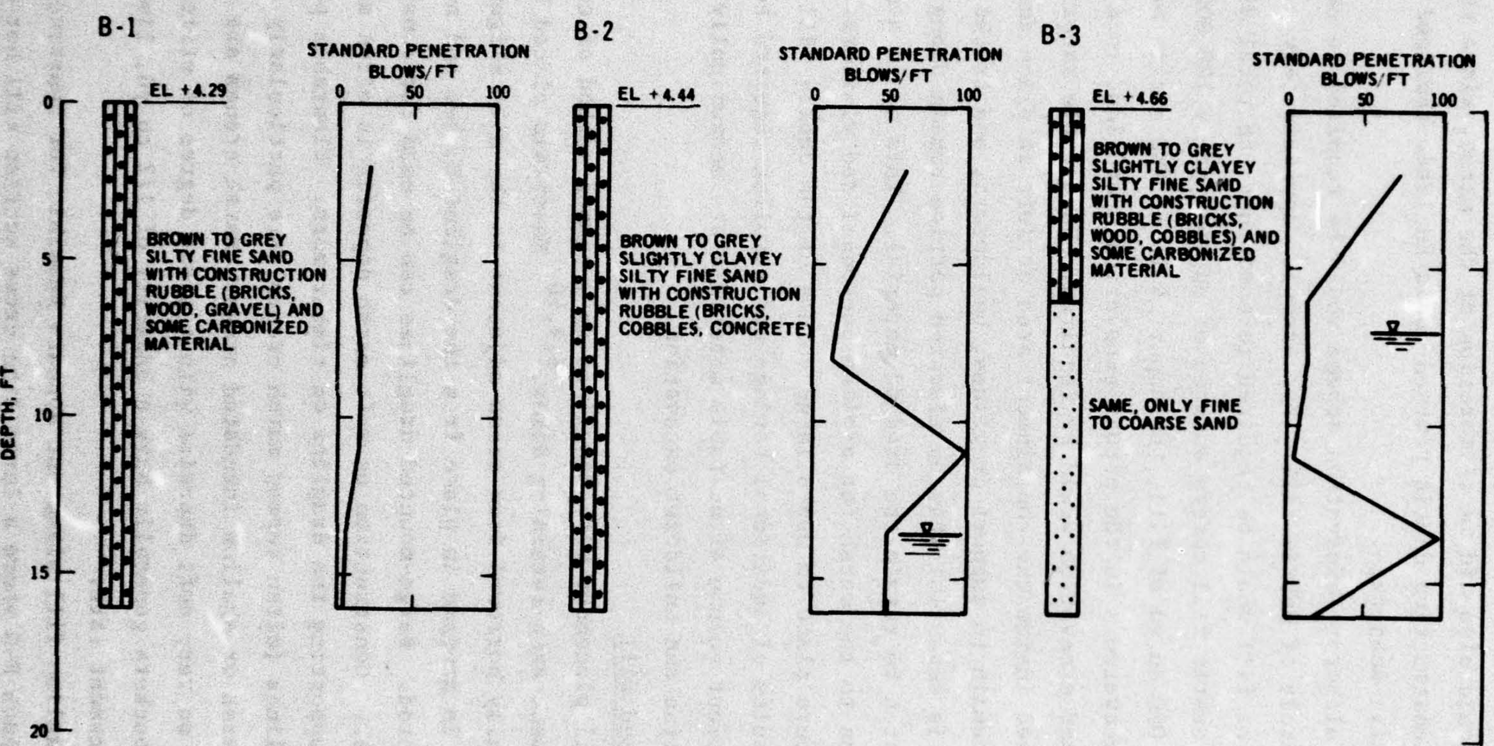


Figure 12. Debris fill area borings (see Figure 7 for boring locations)

debris fill would also aid in restoration of the marsh, since the volume and area of construction debris removed would be later replaced by the dredged material substrate.

48. An elaborate excavation scheme would be required to construct the dike entirely of debris fill. For example, approximately 49,000 cu yd of fill would be required to construct the total dike length. The debris fill covers an area of approximately 100,000 sq ft. To obtain 49,000 cu yd of fill, the upper 14 ft of the entire area would have to be excavated. In the actual excavation operation, localized areas of deeper excavation would be required. Unsuitable materials would be wasted inside the containment area or left in place and elevated areas would remain to support draglines, bulldozers, and trucks. In addition, it is essential that an elevated portion remain along the debris fill area to retain the dredged material. This would also provide access to the marsh for project personnel and visitors.

49. Future plans to use a large volume of the debris fill will depend on results of additional borings and sampling required to ensure that a sufficient volume of suitable materials are economically obtainable by dragline and bulldozer excavation.

Dragline placed fill

50. Fill placement with draglines is a common method of constructing containment area retaining dikes.[8,9,10] Materials placed by dragline are usually borrowed from areas adjacent to the dike alignment. The material is dropped in place from the dragline bucket and normally left uncompacted. Barge-mounted draglines can be used for constructing dikes in water. Construction on soft marsh deposits is often accomplished by supporting the dragline on timber mats. Floatable pontoon-mounted draglines (often termed marsh cranes) are particularly advantageous in marsh or shallow inundated areas. Marsh cranes are capable of operating on very soft deposits with a great degree of efficiency, even though buckets generally have a capacity of 1/2 cu yd, limiting the fill placement rate.

51. Dragline fill placement appears feasible for construction only along dike reach F-G where a large dike cross section will not be required.

This reach of the dike is likely to be intentionally breached within 3 to 6 months after the dredging operations are completed. The breaching will allow tidal waters to penetrate the containment area for marsh establishment. Materials from within the containment area adjacent to the dike alignment would likely be satisfactory for construction of a short-term retaining dike. Also, this reach of dike will not be subjected to significant wave action. One or two shallow exploratory borings will be required to determine soil types and foundation shear strengths along dike reach F-G. Presently, it is anticipated that a dike with the dimensions shown in Figure 13 would be satisfactory. The dike would be approximately 6 ft in height with a crest width of 5 ft and slopes of 1V on 3H. Approximately 6,000 cu yd of fill would be required for dike construction along reach F-G. A marsh crane working along the marsh border could be used to construct the dike.

52. The possibility of using a barge-mounted dragline for construction along dike reaches A-B and B-C was considered. If coarse-grained materials were available directly adjacent to these reaches, dragline construction would be economically feasible. However, borings along dike reach A-B have shown that suitable construction materials are not available within the working range of a barge-mounted dragline.

Hand-placed sandbags

53. Hand placement of sandbags was considered as a possible method for dike construction along the marsh border (dike reach F-G) or for filling gaps on the debris fill area and wooded island. The Corps of Engineers Vicksburg and New Orleans Districts were contacted to obtain cost estimates for sandbag placement. District personnel advised that commercial filling of small sandbags (0.75 cu ft), hauling to the site, and hand placing generally costs approximately $2.00 per bag. The cost could be greater in the Washington area. Sandbags would be an uneconomical alternative for any large-scale operation but might be feasible for adding freeboard to a few low areas (for example, along the wooded island and debris fill, or as a remedial treatment in cases of localized dike settlements).

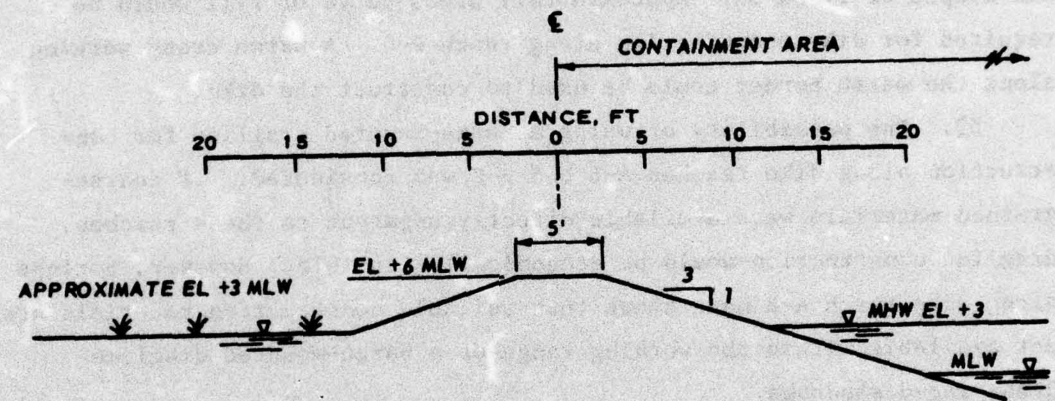


Figure 13. Typical dragline fill section for reach F-G

Effluent Control

54. Sluice structures will be required for draining the containment area during and after the filling operations. The two basic types of sluices are the drop inlet sluice shown in Figure 14 and box sluice shown in Figure 15.

55. The drop inlet sluice is most commonly used in Corps of Engineer confined disposal operations. The structure consists of a half-cylinder corrugated metal pipe riser equipped with a gate of several stoplogs or flashboards that serve as a variable height weir in that they can be added or removed as necessary to control flow into and out of the containment area. The main purpose of the adjustable weir is to control suspended solids in the effluent by allowing drainage of only the upper few inches of supernatant that has a low suspended solids content. A discharge pipe leads from the base of the riser through the dike to the exterior.

56. The box sluice consists of an open cut through the entire dike section. The cut is usually lined with timber, but could be lined with concrete or steel. Box sluices also use stoplogs for controlling drainage. Box sluices are not often employed because of two reasons: susceptibility to failure caused by seepage and subsequent piping along the dike-sluice contact and the high construction costs where dike sections are wide. Box sluices are, however, capable of rapidly discharging large volumes of water. This feature could prove advantageous in marsh establishment since, after a period of consolidation, it will be necessary to allow natural tidal flow throughout the containment area. It is suggested that both types of sluice structures be considered in the detailed design. Presently, however, it is anticipated that the dike along reach F-G can be breached to allow tidal flow through the area. Consequently, the preferred drop inlet sluice will likely prove satisfactory.

57. Sluice structures should be placed in the two locations shown in Figure 7 to avoid possible short circuiting of flow to the sluices and to add flexibility to the filling operation. Discharge through

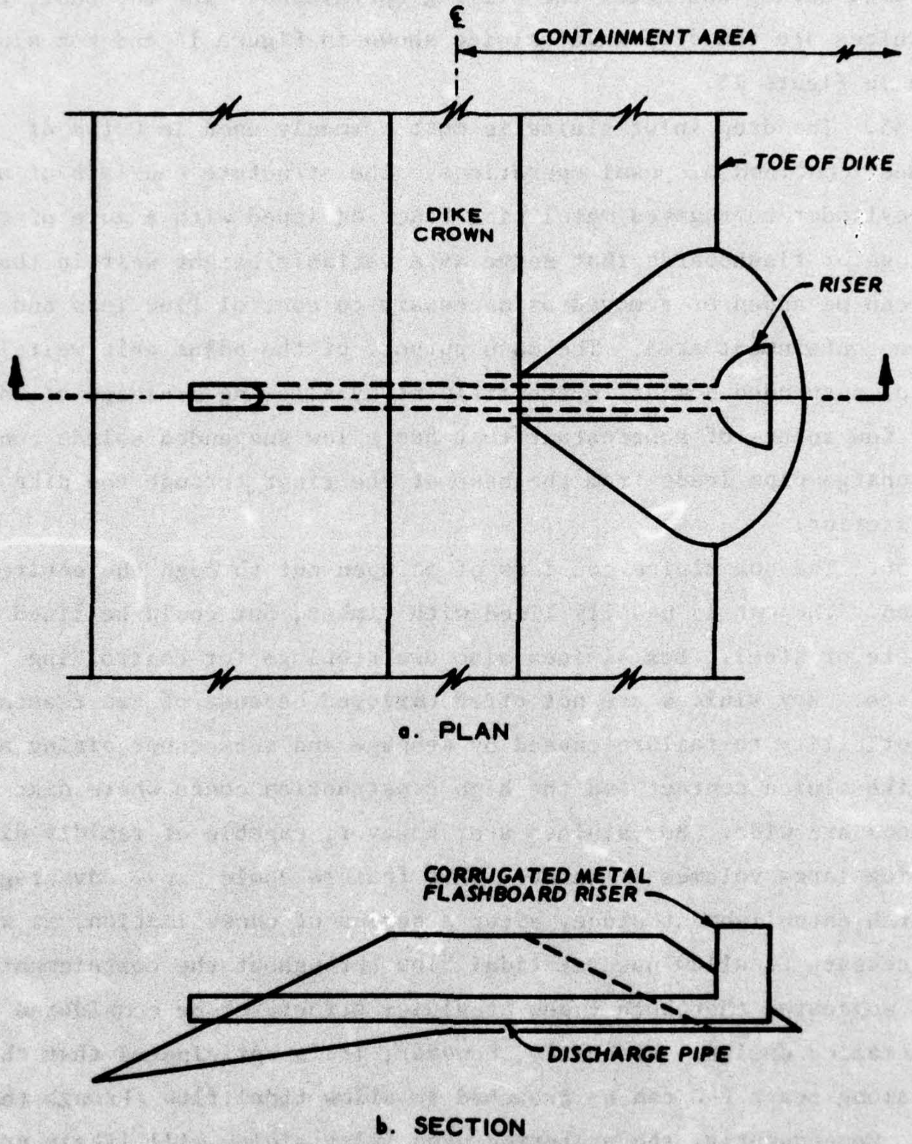


Figure 14. Plan and section views of drop inlet sluice (pipe and riser)

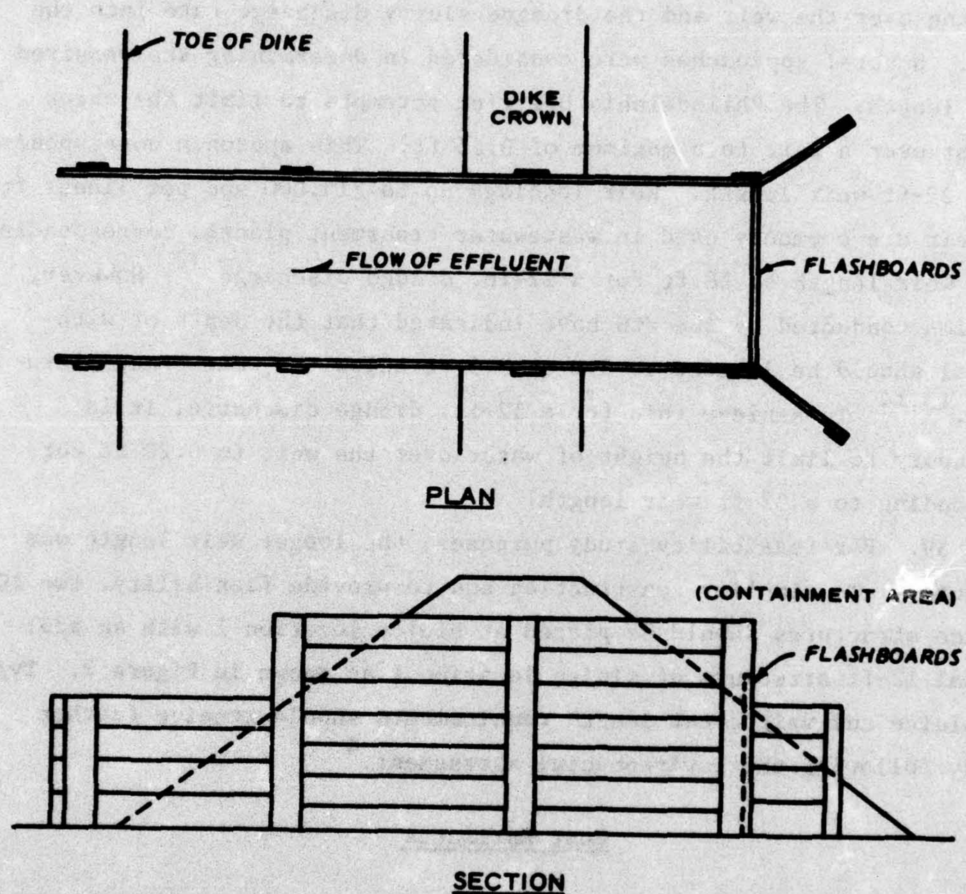


Figure 15. Plan and section views of box sluice

sluice 2, located at the apex of the existing cove along dike reach F-G, would flow through the proposed culvert or open channel and into the existing inlet. Discharge through sluice 1, located in dike reach D-E, would flow directly into the existing inlet.

58. The required weir crest length (i.e., length of stoplogs or flashboards) is dependent on the maximum allowable height of water passing over the weir and the dredged slurry discharge rate into the area. Several approaches were considered in determining the required weir length. The Philadelphia District attempts to limit the water height over a weir to a maximum of 0.25 ft. This approach corresponds to a 22-ft weir length. Weir loadings up to 215,000 gpd per linear ft of weir are commonly used in wastewater treatment plants, corresponding to a weir length of 28 ft for a 12-in. dredge discharge.[12] However, studies conducted by the WES have indicated that the depth of withdrawal should be limited to 3.0 to 3.5 ft below the weir crest elevation.[13,14] To achieve this for a 12-in. dredge discharge, it is necessary to limit the height of water over the weir to 0.20 ft corresponding to a 32-ft weir length.

59. For feasibility study purposes, the longer weir length was selected. To simplify construction and to provide flexibility, two 10-ft sluice structures should be placed at sluice location 1 with an additional 12-ft structure at sluice location 2 as shown in Figure 7. Type of sluice and weir crest length requirements should receive further study following the environmental assessment.[4]

Cost Estimates

60. Costs estimated for dredging and retaining dike construction were based on the following unit prices for fill placement:

Item	Cost
Dredging, per cu yd	$ 1.25
Hydraulically placed fill, per cu yd	1.25
End-dumped debris fill, per cu yd	3.75
End-dumped sand and gravel, per cu yd	7.00
Dragline placed fill, per cu yd	2.00
Slope protection (riprap), per cu yd	23.00
Filter cloth, per sq ft	0.15

The unit prices were determined from discussions with personnel at the Baltimore, Philadelphia, and Charleston District Offices, Corps of Engineers.

61. Construction costs for individual dike reaches are summarized in Table 2. Locations of dike reaches are shown in Figure 7. Costs were determined for each construction technique considered feasible for an individual dike reach. In Table 2, the following information is given for dike reaches A-B, B-C, D-E, and F-G:

<u>a</u>. Length, slope, and crest width of dike.

<u>b</u>. Volume of fill required.

<u>c</u>. Volume of riprap required.

<u>d</u>. Unit prices for fill placement.

<u>e</u>. Total construction costs.

Also included in Table 2 are dike reaches G-D and E-A, which correspond to the elevated debris fill area and wooded island, respectively. Only a total construction cost is estimated for these two reaches.

62. Retaining dike construction cost will vary depending on the construction method used for individual dike reaches. In Table 3 containment area construction costs are summarized for eight different dike construction options. Containment area construction costs were determined by adding $20,000 for sluice construction to the dike construction cost under each option. Containment area construction costs among the eight options ranged from $183,500 to $419,500. However, among options 1 through 5, cost estimates ranged from $183,500 to $211,500 (only a 15-percent cost spread). Under options 1 through 5, dike construction would involve primarily hydraulic, dragline, and end-dumped debris fill. The lowest cost estimate was for option 1 ($183,500) in which dike reaches A-B, B-C, and D-E would be hydraulically constructed and the other dike reaches would be dragline constructed. In options 6 and 7, dike reaches would be constructed by end-dumping debris fill and by dragline. The $239,000 cost estimate for option 6 represents a 30-percent increase above the lowest cost option. The $261,000 cost estimate for option 7 represents a 42-percent increase above the lowest cost option. The maximum cost estimate was for option 8 ($419,500) in which all dike

construction would be by end-dumping sand and gravel. This represents a 137-percent increase above the lowest cost option. It is concluded that using large quantities of the debris fill or commercially available sand and gravel will significantly increase dike construction costs; therefore, the dikes should be constructed using hydraulic fill where possible.

63. The containment area cost per cubic yard of capacity was also computed for two separate cases under the various construction options. Under Case A, material for hydraulic dike construction would be obtained from the shoal area to be dredged with this volume considered as containment area capacity. Under Case B, material for dike construction would be obtained outside the shoal area and thus is not considered as part of the containment area capacity.

64. For Case A, the cost per cubic yard of capacity ranges from \$0.48 to \$1.44 for the eight options. Costs for options 1 through 5 using hydraulic fill for dikes ranged from \$0.48 to \$0.57, only a 20-percent difference. For Case B, the volume of hydraulic dike fill using material from outside the shoal significantly reduces the capacity of the area. This reflects higher costs per cubic yard capacity under Case B for options 1 through 5. These comparisons show that use of shoal material for hydraulic dike construction will significantly lower the costs per cubic yard of capacity and, therefore, the shoal material should be used to the greatest extent possible.

PART IV: RETAINING DIKE DESIGN

65. The preliminary design of the sand-fill retaining dike for feasibility purposes was undertaken in a manner identical to that of any earthen embankment. Results of field investigations and laboratory testing were used in conventional engineering analysis for retaining dike stability and evaluation of potential dike settlement.

66. General requirements for design of earthen embankments have been outlined in appropriate Corps of Engineers (CE) design manuals,[15,16] and factors relating specifically to retaining dike design have been defined by DMRP research.[8]

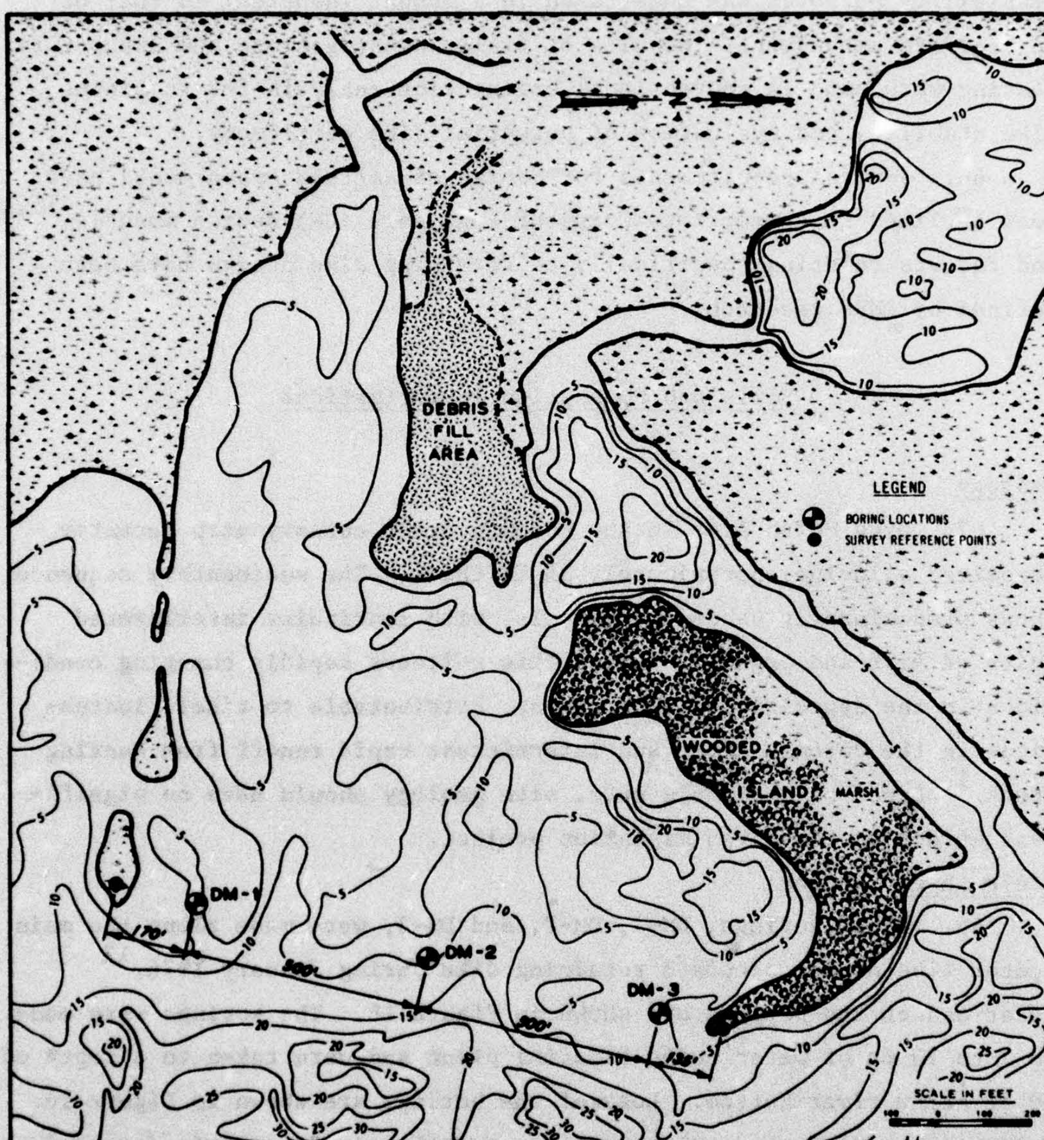
Soils and Foundation Investigations

Geology

67. Dyke Marsh lies in the Potomac River estuary atop recently deposited alluvium approximately 35 ft thick. The sedimentary sequence shows predominantly sands and gravels, with lenticular interlayered units of silt and organic clays. This reflects rapidly changing conditions in the depositional environment, attributable to tidal fluctuations in the Potomac River and intermittent rapid runoff from Hunting Creek.[1] Based on available data, site geology should have no significant effect on the marsh expansion project.

Field investigation

68. Three borings, DM-1, DM-2, and DM-3, were made along the main center line of the proposed retaining dike during January 1976.[17] Locations of the borings are shown in Figure 16. The borings were made in 7 to 10 ft of water using floating plant and were taken to a depth of 50 ft below river bottom. Logs of the borings are shown in Figure 16. Three-inch undisturbed tube samples were taken in fine-grained material; split-spoon samples were taken in cohesionless soils. Standard penetration resistances were also recorded with a 1-3/8-in. I.D., 2-in. O.D. split spoon using a 140-lb hammer with a 30-in. drop. Blow counts were recorded with the boring logs.



NOTE: CONTOURS ARE IN FEET
BELOW MEAN LOW WATER.

Figure 16. Foundation boring locations

Laboratory testing

69. Laboratory soils testing was performed by the Baltimore District soils laboratory in accordance with accepted CE procedures.[18] All undisturbed and split-spoon samples were classified under the Unified Soil Classification System (USCS), and water content determinations were made for all fine-grained samples. Atterberg limits were performed on selected samples of fine-grained material. Grain-size analyses were performed on portions of all undisturbed samples and on selected samples of sands. Shear strength tests consisted of unconfined compression tests performed on selected samples of clays and consolidated undrained R triaxial tests on selected silt samples. Triaxial tests were performed by the WES Soils and Pavements Laboratory. Results of all tests are shown with the boring logs in Figure 9, and test results for selected samples of clays and silts are summarized in Table 4. Individual test data are presented in Appendix B.

Soil conditions

70. Soil conditions beneath the main retaining dike reach A-B are represented by the generalized soil profile presented in Figure 17, which was extrapolated from the foundation boring results. The river bottom material in this vicinity consists of soft clayey silts with lenses of soft clays extending from average elevations of -10.0 ft MLW to -30.0 ft MLW. A stratum of loose silty sands underlies the upper layer extending to approximate elevation -43.0 ft MLW. Standard penetration test results indicate firmer material consisting of sand, silty sands, and silts below elevation -43.0 ft MLW. Conditions represented by the generalized soil profile were used in analyses for retaining dike stability.

Retaining Dike Stability

71. Dike sections for both end-dump construction and hydraulic fill construction were analyzed for three possible failure conditions that might occur under field conditions.

72. The most critical condition encountered for a retaining dike

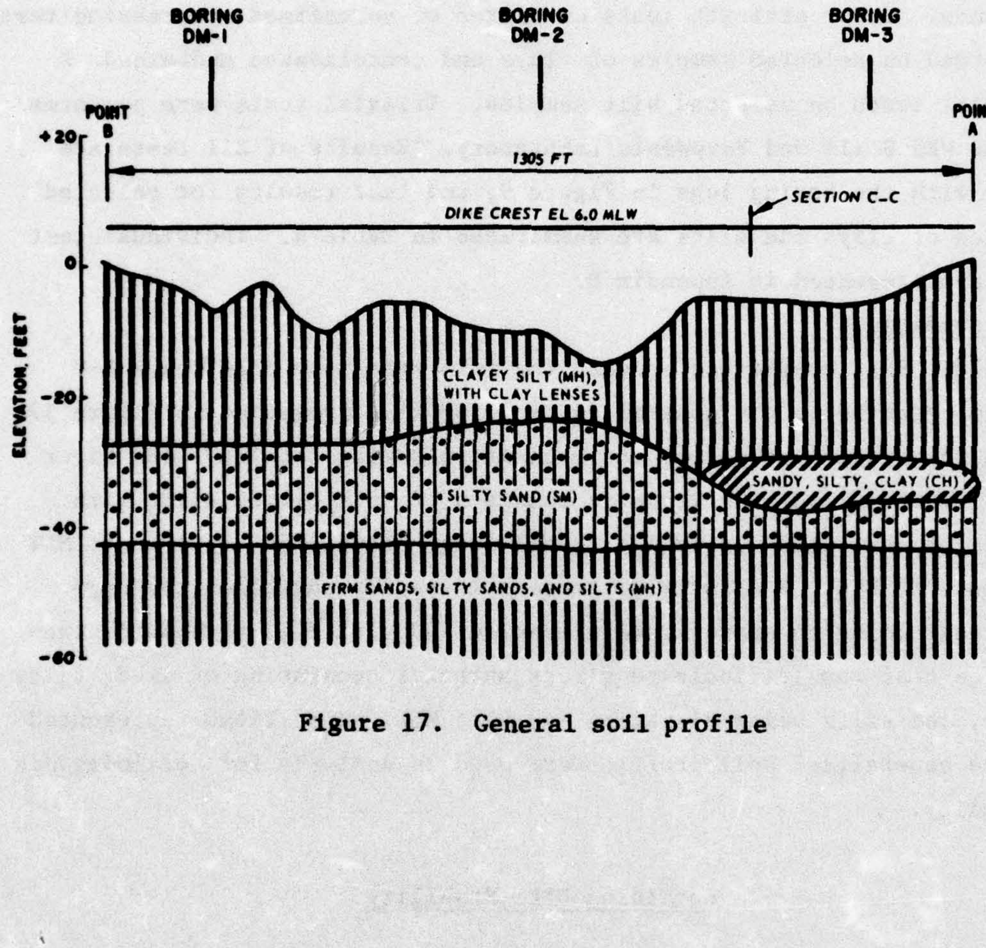


Figure 17. General soil profile

placed on soft foundation soils occurs immediately after placement of the dike and is termed the end-of-construction case. This case considers the condition at which foundation soils have not yet undergone consolidation and shear strength has not yet increased due to placement of the embankment load.

73. Once dredged material is placed in the containment area, a condition of steady-state seepage from the higher marsh substrate to the mean low tidal elevation may develop. This case is the long-term or steady seepage condition and was also considered in design of the retaining dike.

74. The tidal fluctuation of approximately 3 ft at Dyke Marsh can also subject the retaining dike to a condition at which the water level is lowered at a faster rate than the dike and foundation material can drain. This can result in excess pressures and seepage forces and is termed the sudden-drawdown case. This case was also considered in retaining dike design.

Shear strength

75. Shear strengths for the retaining dike stability analyses were chosen based upon laboratory tests on foundation soils as summarized in Table 4 and on previous CE experience with similar soils. The unconsolidated undrained (Q) strength for foundation clays and consolidated undrained (R) strength for foundation silts were chosen from plots presented in Appendix B. Table 5 summarizes design shear strengths selected for the unconsolidated undrained (Q), consolidated undrained (R), and consolidated drained (S) conditions. Dike fill material was assumed to have shear strengths identical to that of other sands for both hydraulic fill and placed dike sections. In the analyses, dredged material was assumed to have no shear strength.

Stability analyses

76. Analyses were performed to determine the stability of both hydraulic fill and placed dike sections. For feasibility study purposes, a location along the main dike center line was chosen for analyses. Other dike sections including the back dikes will be analyzed for stability during the detailed design phase.

77. The location chosen for analysis is shown as section C-C in Figure 8 and on the generalized soil profile in Figure 17. The section reflects the most critical foundation conditions indicated by the borings.

78. The stability analyses were made using procedures outlined in appropriate CE design manuals.[15,16] Both the circular arc method and wedge method of slope stability were employed and computer programs developed at WES were used to aid the analysis.[19,20]

79. Stratification used in the analysis was based on boring DM-3, which was considered to represent the most critical subsurface conditions. Shear strengths for the dike core and foundation soils were chosen as described in previous paragraphs. The end-of-construction case was analyzed using Q-strengths for clays, R-strengths for silts, and S-strengths for sands. Sudden drawdown analyses used R-strengths for clays and silts and S-strengths for sands. The long-term case was analyzed using S-strengths for all soils.

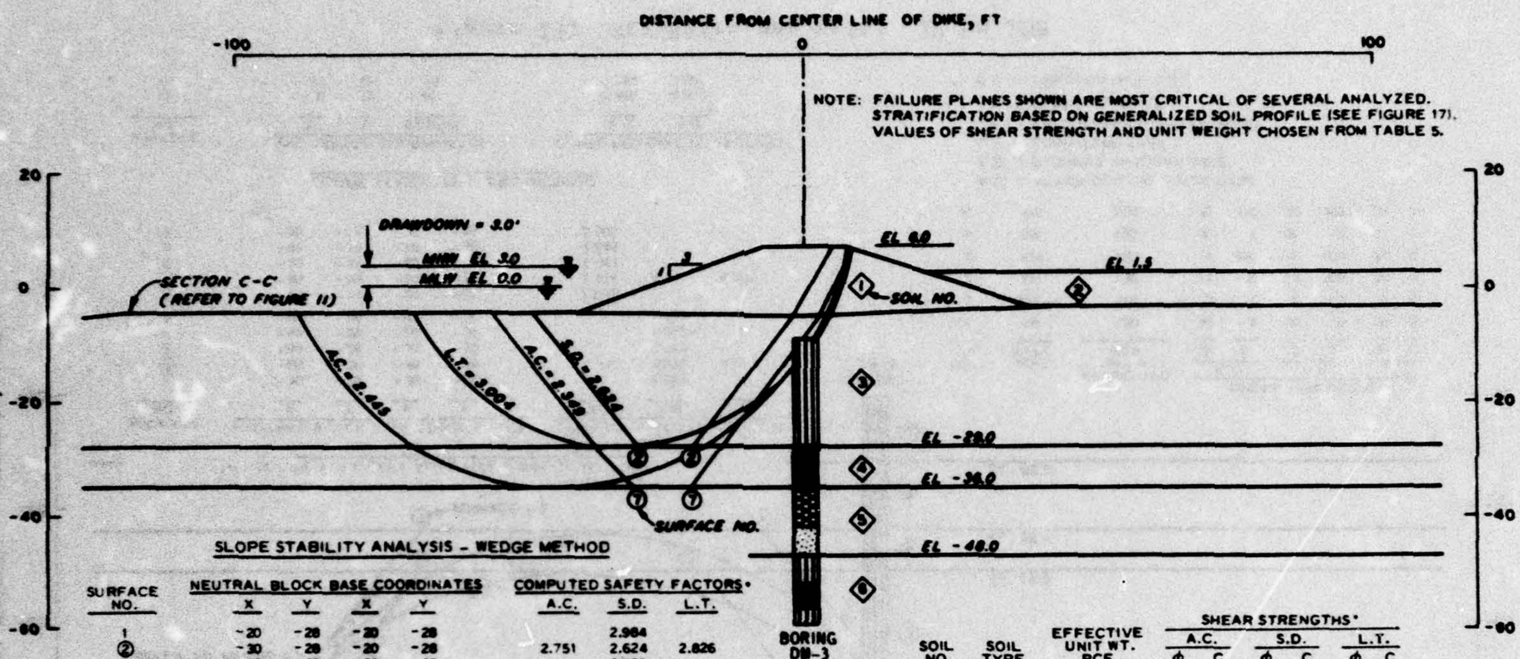
80. Figures 18 and 19 illustrate the parameters used in the stability analysis and results. A minimum factor of safety against shear failure of 1.3 is considered adequate for retaining dikes and was used in this preliminary design.

81. Minimum factors of safety for the given conditions were found by varying the locations of potential failure surfaces. As might be expected for the stratified soil conditions, lower factors of safety were computed for the wedge method of analysis. The end-of-construction case was found to be the most critical of the possible failure conditions analyzed.

82. Based upon the stability analyses, a 1V-on-3H slope for the placed dike section is considered adequate. Slopes expected to be attained by hydraulic fill are well within acceptable stability criteria.

<u>Dike settlement</u>

83. Borings along the main dike center line indicate a predominantly silt and silty sand foundation. Minor displacement of the softer silts during dike construction and negligible settlement of the dike due to later consolidation of the foundation would be expected to occur.



SLOPE STABILITY ANALYSIS – WEDGE METHOD

SURFACE NO.	NEUTRAL BLOCK BASE COORDINATES X	Y	X	Y	COMPUTED SAFETY FACTORS* A.C.	S.D.	L.T.
1	-20	-28	-20	-28		2.984	
2	-30	-28	-20	-28	2.751	2.624	2.826
3	-40	-28	-20	-28		2.796	
4	-30	-28	-10	-28		2.868	
5	-30	-28	-30	-28		3.154	
6	-20	-35	-20	-35	2.871		
7	-30	-35	-20	-35	2.349	2.966	3.064
8	-40	-35	-20	-35	2.356		
9	-30	-35	-10	-35	2.505		
10	-30	-35	-30	-35	2.902		

SLOPE STABILITY ANALYSIS – ARC METHOD

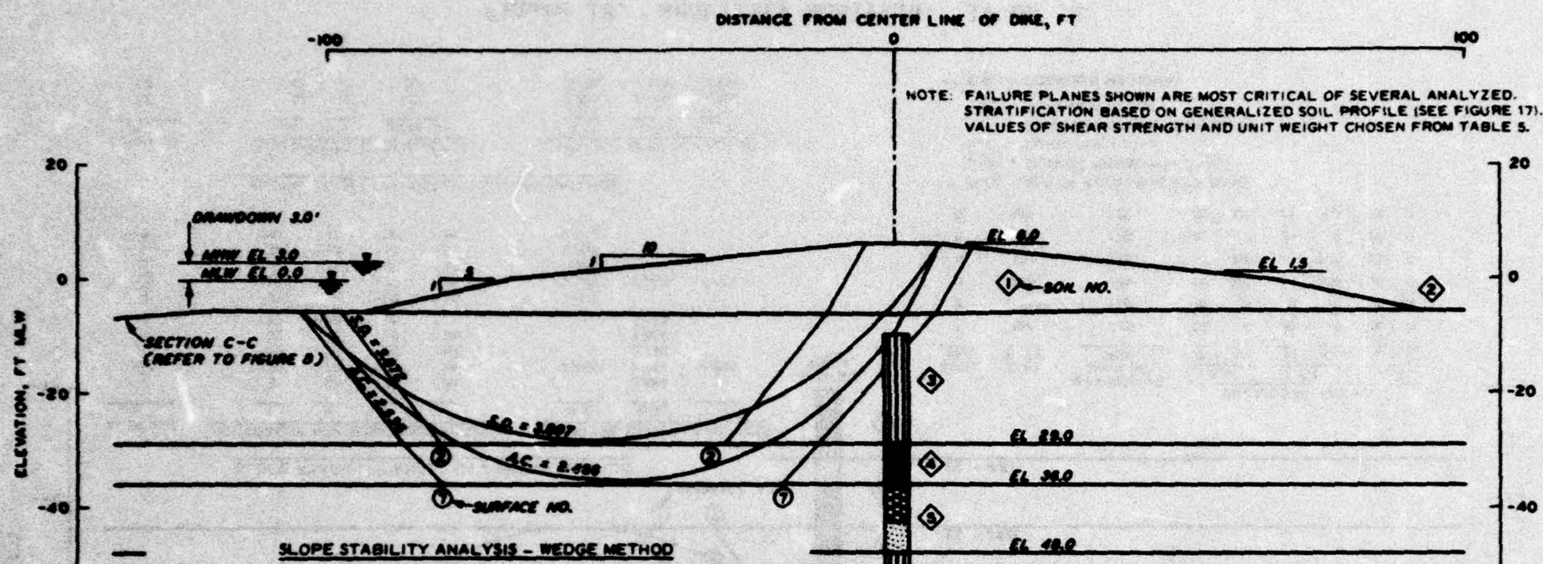
SURFACE NO.	ARC CENTER COORDINATES X	Y	RADIUS	COMPUTED SAFETY FACTORS* A.C.	S.D.	L.T.
11	-32	12	40	3.205	3.114	3.004
12	-42	15	50	2.445	3.933	3.335

SOIL NO.	SOIL TYPE	EFFECTIVE UNIT WT. PCF	SHEAR STRENGTHS* A.C. φ	A.C. C	S.D. φ	S.D. C	L.T. φ	L.T. C
1	SM	120	30	0	30	0	30	0
2	D.M.**	110	0	0	0	0	0	0
3	MH	130	14	300	14	300	28	0
4	CH	120	0	250	10	500	22	0
5	SM	120	30	0	30	0	30	0
6	MH	120	20	300	20	300	28	0

* A.C. = AFTER CONSTRUCTION CASE
S.D. = SUDDEN DRAWDOWN CASE
L.T. = LONG-TERM CASE
φ = FRICTION ANGLE IN DEGREES
C = COHESION IN PSF

** D.M. = DREDGED MATERIAL

Figure 18. Stability analysis: 1V on 3H



SLOPE STABILITY ANALYSIS – WEDGE METHOD

SURFACE NO.	NEUTRAL BLOCK BASE COORDINATES X	Y	X	Y	COMPUTED SAFETY FACTORS* A.C.	S.D.	L.T.
1	-70	-28	-30	-28		3.903	
2	-80	-28	-30	-28	4.042	3.872	4.523
3	-90	-28	-30	-28		4.017	
4	-80	-28	-20	-28		3.892	
5	-80	-28	-40	-28		4.098	
6	-70	-35	-20	-35	2.626		
7	-80	-35	-20	-35	2.536	4.104	4.339
8	-90	-35	-20	-35	2.543		
9	-80	-35	-10	-35	2.640		
10	-80	-35	-30	-35	2.588		

SLOPE STABILITY – ARC METHOD

SURFACE NO.	ARC CENTER COORDINATES X	Y	RADIUS	COMPUTED SAFETY FACTORS* A.C.	S.D.
11	-50	25	60	2.466	4.090
12	-53	42	70	3.949	3.807

SOIL NO.	SOIL TYPE	EFFECTIVE UNIT WT. PCF	SHEAR STRENGTHS* A.C. ϕ	A.C. C	S.D. ϕ	S.D. C	L.T. ϕ	L.T. C
1	SM	120	30	0	30	0	30	0
2	D.M.**	110	0	0	0	0	0	0
3	MH	130	14	300	14	300	28	0
4	CH	120	0	250	10	500	22	0
5	SM	120	30	0	30	0	30	0
6	MH	120	20	300	20	300	28	0

* A.C. = AFTER CONSTRUCTION CASE
S.D. = SUDDEN DRAWDOWN CASE
L.T. = LONG-TERM CASE
ϕ = FRICTION ANGLE IN DEGREES
C = COHESION IN PSF

** D.M. = DREDGED MATERIAL

Figure 19. Stability analysis: 1V on 10H

84. Displacement and dike settlement along reach F-G will be considered in the detailed design phase; however, the magnitude of settlement would be small unless the foundation material is extremely weak in this area. Nevertheless, the foundation loading in this reach will not be great, and dike stability and settlement is not considered as a significant problem.

Slope Protection

85. Requirements for retaining dike slope protection were examined considering both scour due to river current and erosion due to wave action. Maximum current velocities for Jones Point, Alexandria, immediately north of Dyke Marsh, are 1.64 fps.[21] This is well below the suggested maximum mean scour velocity of 2.0 fps for fine sand.[22] Additionally, the channel velocity at Dyke Marsh should be substantially lower than at Jones Point due to the depositional nature of the area as described in previous paragraphs. No slope protection due to river current velocity is therefore required.

86. Slope protection requirements for erosion due to wave action are dependent upon the embankment slope angle, prevailing winds, and fetch distance affecting the significant wave height.

87. Slope protection is not required for hydraulic-fill embankments with 1V-on-10H slopes. However, the steeper slopes obtained by end-dump construction will require protection against excessive wave erosion. A 12-in.-thick layer of riprap extending from the dike crest to a maximum of 3 ft below MLW would be needed along the exterior slopes of dike reaches A-B, B-C, and D-E. The riprap should be well graded, having a maximum rock size of 100 lb, median rock size of 25 lb, and minimum rock size of 3 lb. Filter cloth will be required beneath the riprap layer to prevent erosion of embankment material by water penetrating the riprap layer. Slope protection was designed to withstand a 2-ft maximum wave height. This wave height was predicted from examination of a limited amount of wind data and application of graphs and procedures contained in the Shore Protection Manual.[23] Riprap layer thickness and stone sizes

were computed based on information given in EM 1110-2-2300 and the following equation:*

$$W_A = \frac{(62.4)\ G\ H^3}{4.37(G-1)^3 \cot \alpha}$$

where

W_A = median rock size, lb

G = specific gravity

H = significant wave ht, ft

α = embankment slope angle, deg

88. Although preliminary conventional analysis indicates that no slope protection is required for the hydraulic-fill section, additional studies should be undertaken in the detailed design phase to further establish stability of this section against wave erosion. Previous studies have suggested that examination of the physical properties and controlling conditions at existing stable beaches is a desirable means of determining stability of man-made slopes against wave erosion.[9] Stable beach slopes along the wooded island adjacent to the main retaining dike should be analyzed in this manner during the detailed design phase.

* Equation to be published by the U. S. Army Corps of Engineers in an Engineering Technical Letter.

PART V: GUIDELINES FOR DREDGED MATERIAL PLACEMENT

Requirements

89. General requirements for dredged material placement were formulated considering factors relating to one-time, confined placement for marsh creation defined by DMRP research.[24] The final elevation of material within the containment area should range from approximately -1.0 ft MLW to +3.0 ft MLW with the exception of one or two localized mounds ranging in elevation from +5.0 ft MLW to +8.0 ft MLW. These elevation requirements will place the majority of the dredged material surface within the intertidal zone, which is necessary for marsh creation. Allowing for an estimated dredged material consolidation of 1 ft, the containment facility will be initially filled to elevation +2.5 ft MLW.

90. The NPS has requested that localized surface mounding be created to the greatest extent possible by the dredging operation. To form the mounded areas, the dredged material must consist of silty sand or coarser material. The sediment samples indicate that a zone of silty sand may exist in the southern portion of the shoal (samples 11, 15, 17, and 18, Appendix A). This zone should contain sufficient material suitable for mound construction.

91. In many confined disposal operations, the dredged material is discharged from only *one* outlet, usually located as far from the sluice as possible. This procedure cannot be employed at the Dyke Marsh containment area. Discharge points at different locations will be required to form the mounds and to ensure that the dredged material is distributed uniformly throughout the area. A multiple-point discharge line will also be considered in the final design to improve efficiency of the filling operation.

Dredging Operation

92. The dredging operation described below is a tentative plan

designed to satisfy the dredged material surface elevation requirements with a minimum of pipe rehandling within the containment area.

93. Filling the containment area would begin by constructing mounds at the two locations shown in Figure 20. Dredge pipes would be extended into the containment area reaching the proposed mound locations. The dredge pipe within the containment area will be supported on pontoons with the end of the pipe supported approximately 5 ft above the water level. During dredging, the water surface elevation within the containment area will be maintained at approximately +3.0 ft MLW. This will allow the building of mounds to elevations approaching +8.0 ft MLW. Mounds will be formed by initiating dredging within a sand or silty sand zone of the shoal. In mound construction spreaders should be used at the discharge pipe outlet. Sections of pipe can be added as necessary to extend the mounded area as material is built up directly beneath the outlet. These additional sections of pipe would be supported on the mounded material.

94. The volume of material available for mounding will be determined prior to dredging. Mound 1 will be constructed first with dredged quantities estimated periodically to ensure that a sufficient volume of suitable material remains for constructing mound 2. Construction of mound 2 will begin following the completion of mound 1. While discharging at point 2, the dredge pipe should be closed off at point 1. Upon completion of mound 2, the remainder of the containment area should be filled by alternating discharge between the immediate areas of point 1 and 2.

95. Effluent suspended solids should be monitored at the sluices during dredging. At times, sluice 1 should be closed to increase flow of material into the cove area south of the debris fill.

Production Rate

96. The BD has tentatively planned on the use of a 12-in. pipeline dredge for this project. Based on surface loading rates, it is anticipated that effluent suspended solids requirements can be met while

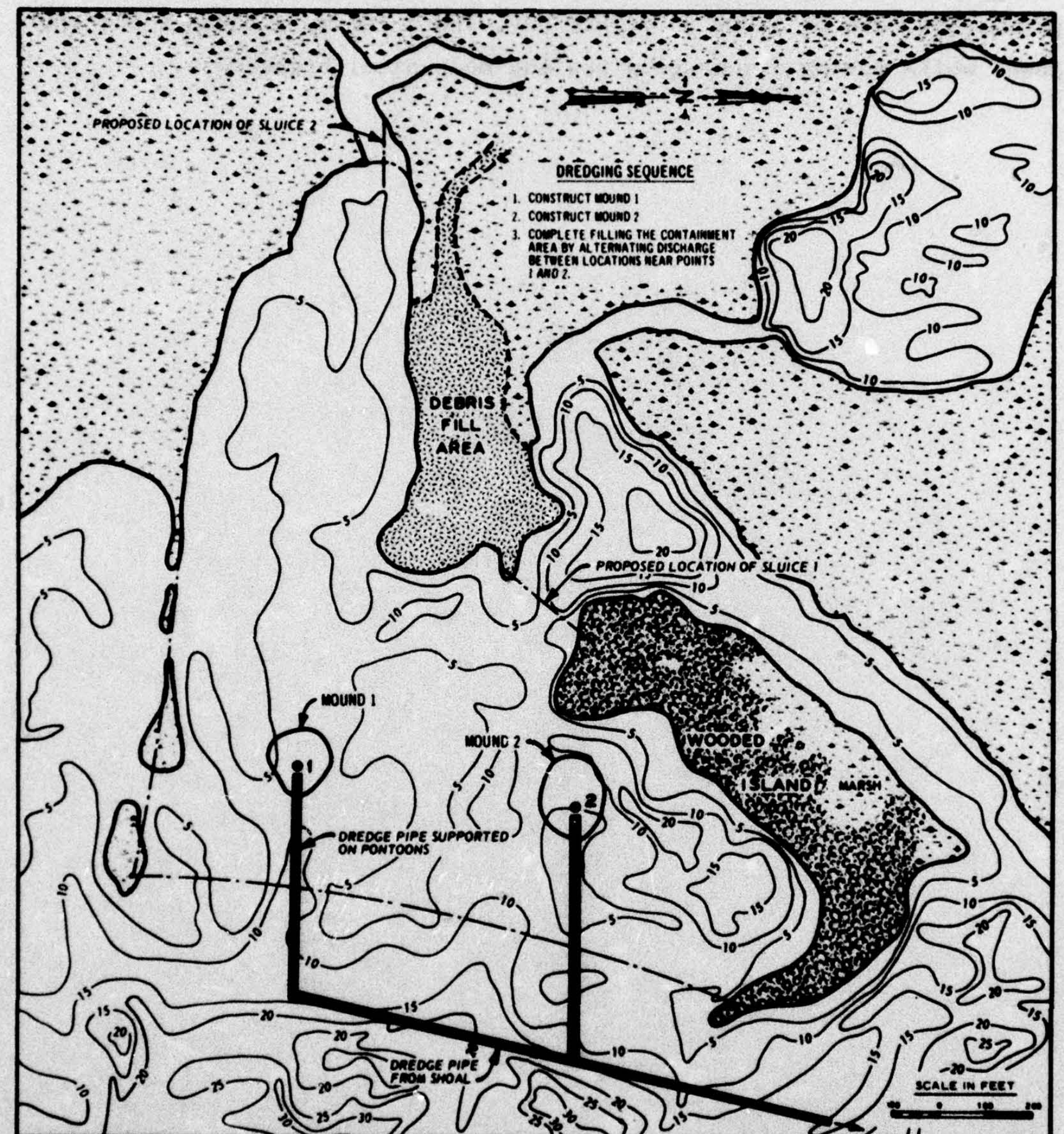


Figure 20. Dredged material placement scheme

dredging continuously. It is, therefore, estimated that the containment area can be filled in a 65-day period. This estimate is based on an assumed 275,000 cu yd of in situ channel material to be dredged, production rate of 5,000 cu yd per day, and a 10-day allowance for shutdowns while moving discharge pipes and mechanical breakdowns.

PART VI: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

97. Based upon the preliminary studies reported herein, construction of retaining dikes and appurtenant structures and placement of dredged material for marsh expansion is feasible at the project location.

98. There are a number of potential benefits derived from using dredged material for marsh expansion as outlined in this study. The project will provide the initial step toward productive marshland development at Dyke Marsh, partially fulfill the Congressional intent to restore Dyke Marsh, provide a viable and productive method for disposal of dredged material, and add data for research concerning use of dredged material for habitat development. Feasibility is demonstrated by the following specific conclusions:

- a. The proposed demonstration area location and size is adequate for demonstration purposes, being large enough to accommodate immediate dredging requirements and to evaluate the feasibility of complete development of the marsh in an incremental fashion. Also the total expanded area of 28 acres will significantly add to the area of productive marshland at Dyke Marsh.
- b. Surface sampling of the shoal indicates that the sediment material is suitable for marsh substrate with sufficient quantities of coarse-grained material available to ensure small settlements and relatively fast stabilization of the marsh.
- c. A retaining dike system constructed from locally available material is the optimum method of dredged material containment.
- d. Hydraulic fill is the method recommended for construction of dike reaches A-B and B-C shown in Figure 7.
- e. Coarse sands available in the shoal to be dredged should be used to the greatest extent possible in dike construction to minimize turbidity generation. If sufficient quantities of coarse sands are not available within the specified dredging limits, the balance should be acquired by over-dredging or by use of available silty sands within the shoal.
- f. End-dumped fill is the recommended method of construction

for dike reach D-E shown in Figure 7. This relatively short reach is suitably located for end-dump construction, and this method would be best suited for placement of material and construction of the sluice located in this reach.

g. Material for end-dump construction should be borrowed from the debris fill area adjacent to reach D-E. The upper 4 to 5 ft of this area will be used to construct the reach and later replaced by dredged material, thereby adding to the area of expanded marshland.

h. Dragline-placed fill is the recommended method for construction of dike reach F-G. An amphibious dragline should be used to construct the dike by borrowing material adjacent to the dike alignment.

i. Minor diking may be required along the debris fill area and wooded island; sandbags or amphibious dragline-placed fill should be employed in these areas.

j. Suitable sluice structures with an effective weir length of 32 ft should be placed in dike reaches D-E, and F-G, shown in Figure 7.

k. Soil conditions along the main dike reaches (as indicated by limited field and laboratory investigations) are adequate to support the retaining dike.

l. Stability analyses performed indicate that both hydraulic-fill and dumped-fill dike sections along the dike center line A-B are well within acceptable stability criteria.

m. Minor displacement of soft bottom material will occur during dike construction, but long-term settlements of the dike should be negligible.

n. The above combination of recommended construction procedures is the optimum considering both technical and economic factors.

Recommendations

99. Based upon the preliminary findings of the feasibility study and pending the environmental assessment studies, it is recommended that a detailed design study be initiated from which plans and specifications for dike construction and initial marsh expansion can be prepared. Specific areas which should be examined under the detailed design phase are summarized below:

a. A more detailed sampling and testing program for the

shoal material to be dredged should be undertaken. Core samples in the shoal material will indicate the amount of suitable material available for dike construction and generally characterize the shoal with depth. Concurrent with this effort, a more detailed physical survey of the shoal is required.

b. Information obtained by surveys and shoal material sampling and testing should be used to correlate accurately the in situ sediment and containment area volumes as suggested by DMRP research methodologies. After project completion, field data can be used to determine accuracy of the proposed methodologies.

c. More detailed information regarding the suitability of the debris fill material for construction purposes and the extent and availability of this material should be determined through borings or inspection trenches.

d. Additional study of slope protection requirements for hydraulic-fill dike sections should be made to include characterization of existing stable beaches near the project area.

e. A more detailed survey of the demonstration area location is needed to identify recent changes in conditions and to identify accurately the requirements for diking along the proposed center lines.

f. Retaining dike stability must be analyzed for all dike reaches under the detailed design phase. Additional foundation borings and laboratory investigations of foundation soils will therefore be required.

g. Optimum guidelines for dredged material placement should be developed in detail to shape the expanded marshland for maximum benefits.

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Table 1

Engineering Properties of Sediment to be Dredged

Sample No.*	Unified Soil Classification	Liquid Limit %	Plasticity Index %	D_{10} mm	% Silt or Finer
1	Silt(ML)	47	16	--	62
2	Lean Clay(CL)	43	17	--	62
6	Fat Clay(CH)	70	37	--	78
7	Sand(SP-SM)	--	--	0.09	9
8	Clayey Silt(MH)	94	50	--	95
11	Silty Sand(SM)	45	10	--	46
13	Clayey Gravel(GC)	55	28	0.004	27
14	Sand(SP-SM)	--	--	0.15	7
15	Silty Sand(SM)	33	2	0.0025	36
16	Clayey Silt(MH)	80	37	--	92
17	Silty Sand(SM)	34	2	0.0025	47
18	Silty Sand(SM)	--	--	0.003	28
19	Fat Clay(CH)	70	37	--	91
20	Fat Clay(CH)	73	39	--	83

* Locations of samples shown in Figure 5.

Table 2

Estimated Construction Costs for Individual Dike Reaches*

Dike Reach**	Hydraulic Fill†	Dragline Fill††	Debris End Dumped‡		Sand and Gravel End Dumped‡	
A-B L = 1,250	V = 80,500 C = 1.25 T = 100,500	--	V = 30,500 C = 3.75 T_1 = 114,500	Riprap: V = 1,300 C = 23 T_2 = 30,000 Filter Cloth: T_3 = 5,500	V = 30,500 C = 7 T_1 = 213,500	Riprap: V = 1,300 C = 23 T_2 = 30,000 Filter Cloth: T_3 = 5,500
			$T = T_1 + T_2 + T_3$ = \$150,000		$T = T_1 + T_2 + T_3$ = \$249,000	
B-C L = 700	V = 23,500 C = 1.25 T = 29,500	--	V = 5,000 C = 3.75 T_1 = 19,000	Riprap: V = 500 C = 23 T_2 = 11,500 Filter Cloth: T_3 = 2,000	V = 5,000 C = 7 T_1 = 35,000	Riprap: V = 500 C = 23 T_2 = 11,500 Filter Cloth: T_3 = 2,000
			$T = T_1 + T_2 + T_3$ = \$32,500		$T = T_1 + T_2 + T_3$ = \$48,500	
C-G L = 1,200	--	V = 6,000 C = 2 T = 12,000	V = 9,000 C = 3.75 T = 34,000		V = 9,000 C = 7 T = 63,000	
D-E L = 200	V = 15,000 C = 1.25 T = 19,500	--	V = 4,500 C = 3.75 T_1 = 17,000	Riprap: V = 200 C = 23 T_2 = 4,500 Filter Cloth: T_3 = 1,000	V = 4,500 C = 7 T_1 = 31,500	Riprap: V = 200 C = 23 T_2 = 4,500 Filter Cloth: T_3 = 1,000
			$T = T_1 + T_2 + T_3$ = \$22,500		$T = T_1 + T_2 + T_3$ = \$37,000	
G-D E-A L = 1,800	These reaches correspond to the elevated debris fill area and wooded island -- minor diking anticipated				T = \$1,000	

* Symbols used in this table are: L = length (ft), V = volume (yd^3), C = cost/yd^3 (dollars), T = total cost (dollars).
** Dike reaches to be constructed to el. +6.0 MLW; locations of dike reaches are shown in Figure 1.
† Cross section: slope = 1V on 10H above MLW; slope = 1V on 5H below MLW; crest width = 10 ft. Volumes of hydraulically-placed dikes include an estimated 10% loss of material during placement.
†† Cross section: slope = 1V on 3H; crest width = 5 ft.
‡ Cross section: slope = 1V on 3H; crest width = 15 ft.

	OPTION 1		OPTION 2		OPTION 3	
Item	Constr Method	Cost	Constr Method	Cost	Constr Method	Cost
Dike Reach A-B	Hydraulic	100,500	Hydraulic	100,500	Hydraulic	100,50
Dike Reach B-C	Hydraulic	29,500	Hydraulic	29,500	Hydraulic	29,50
Dike Reach C-G	Dragline	12,000	Dragline	12,000	Dragling	12,00
Dike Reach D-E	Hydraulic	19,500	Debris End-dumped	22,500	Sand and Gravel End-dumped	37,00
Dike Reaches C-D E-A	Dragline	2,000	Dragline	2,000	Dragline	2,00
Sluice	--	2,000	--	2,000	--	2,00
Containment Area, Total Cost	--	183,500	--	186,500	--	201,00
Case A/Cost per cu yd of Capacity**	Disposal Capacity = 384,250 cu yd	0.48	Disposal Capacity = 378,000 cu yd	0.49	Disposal Capacity = 373,500 cu yd	0.54
Case B/Cost per cu yd of Capacity†	Disposal Capacity = 264,750 cu yd	0.69	Disposal Capacity = 274,000 cu yd	0.68	Disposal Capacity = 269,500 cu yd	0.75

* Costs are given in dollars. As used in this table, capacity is the actual contained volume comp

** Case A - Based on assumption that hydraulic sections of dike are constructed from materials with

† Case B - Based on assumption that hydraulic sections of dike are constructed from materials loca

Table 3

Containment Area Construction Costs

OPTION 3		OPTION 4		OPTION 5		OPTION 6		
nstr thod	Cost	Constr Method	Cost	Constr Method	Cost	Constr Method	Cost	Co Me
ulic	100,500	Hydraulic	100,500	Hydraulic	100,500	Debris End-dumped	150,000	Debri End-c
ulic	29,500	Hydraulic	29,500	Debris End-dumped	32,500	Debris End-dumped	32,500	Debri End-c
ing	12,000	Debris End-dumped	34,000	Debris End-dumped	34,000	Dragline	12,000	Debri End-d
and l umped	37,000	Debris End-dumped	22,500	Debris End-dumped	22,500	Debris End-dumped	22,500	Debri End-d
ine	2,000	Dragline	2,000	Dragline	2,000	Dragline	2,000	Dragl
	2,000	--	2,000	--	20,000	--	20,000	-
	201,000	--	208,500	--	211,500	--	239,000	-
al ty = 0 cu yd	0.54	Disposal Capacity = 379,500 cu yd	0.55	Disposal Capacity = 369,250 cu yd	0.57	Disposal Capacity = 339,000 cu yd	0.71	Dispo Capac 340,5
al ty = 0 cu yd	0.75	Disposal Capacity = 275,500 cu yd	0.76	Disposal Capacity = 288,750 cu yd	0.73	Disposal Capacity = 339,000 cu yd	0.71	Dispo Capac 340,5

ained volume computed by assuming a final fill elevation of +1.5 MLW. Mounding, bulking, consolidation, and d
om materials within the shoal requiring dredging.
om materials located outside the shoal requiring dredging.

2

s

OPTION 5		OPTION 6		OPTION 7		OPTION 8	
str hod	Cost	Constr Method	Cost	Constr Method	Cost	Constr Method	Cost
lic	100,500	Debris End-dumped	150,000	Debris End-dumped	150,000	Sand and Gravel End-dumped	249,000
mped	32,500	Debris End-dumped	32,500	Debris End-dumped	32,500	Sand and Gravel End-dumped	48,500
mped	34,000	Dragline	12,000	Debris End-dumped	34,000	Sand and Gravel End-dumped	63,000
mped	22,500	Debris End-dumped	22,500	Debris End-dumped	22,500	Sand and Gravel End-dumped	37,000
ne	2,000	Dragline	2,000	Dragline	2,000	Dragline	2,000
	20,000	--	20,000	--	20,000	--	20,000
	211,500	--	239,000	--	261,000	--	419,500
al ty = 0 cu yd	0.57	Disposal Capacity = 339,000 cu yd	0.71	Disposal Capacity = 340,500 cu yd	0.77	Disposal Capacity = 291,500 cu yd	1.44
al ty = 0 cu yd	0.73	Disposal Capacity = 339,000 cu yd	0.71	Disposal Capacity = 340,500 cu yd	0.77	Disposal Capacity = 291,500 cu yd	1.44

n of +1.5 MLW. Mounding, bulking, consolidation, and displacement of material were not considered.

ng.

3

Table 4

Summary of Test Results on Selected Foundation Soils

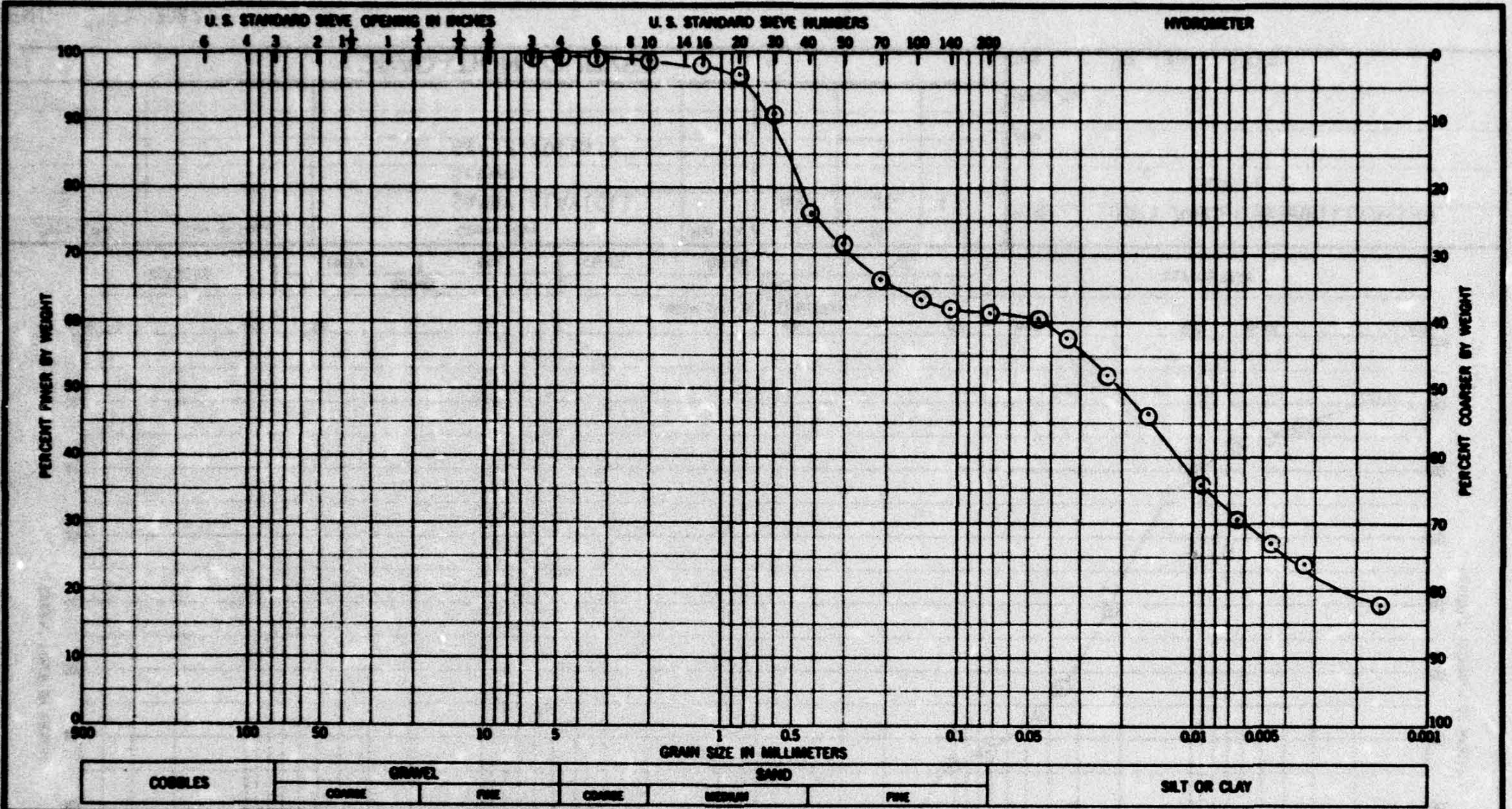
Boring	Sample	Elevation ft, MLW	USCS Classification	Atterberg Limits		Shear Strength		
				LL	PL	Type Test	ϕ deg	Cohesion psf
DM-2	B-3	-18.5	MH	61	31	R	14	800
DM-3	B-3	-18.5	MH	60	35	R	18	0
DM-3	B-7	-28.5	CH	80	36	U.C.	0	179
DM-3	B-8	-33.5	CH	62	30	U.C.	0	252
DM-3	B-9	-35.5	CH	119	44	U.C.	0	349

Table 5

Design Shear Strengths

Material	Unconsolidated Undrained (Q)		Consolidated Undrained (R)		Condolidated Drained (S)	
	φ deg	Cohesion psf	φ deg	Cohesion psf	φ deg	Cohesion psf
Clays	0	250	10	300	22	0
Silts	--	--	14	300	28	0
Sands	--	--	--	--	30	0
Dike Fill	--	--	--	--	30	0

APPENDIX A: LABORATORY TEST RESULTS FOR SEDIMENT SAMPLES



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI	
1		SANDY SILT(ML)		47	31	16	Project DYKE MARSH REHABILITATION
		Brown					Sample 1
		Gs= 2.66(est.)					Area
							Boring No.
GRADATION CURVES							Date 26 Jan., 1976

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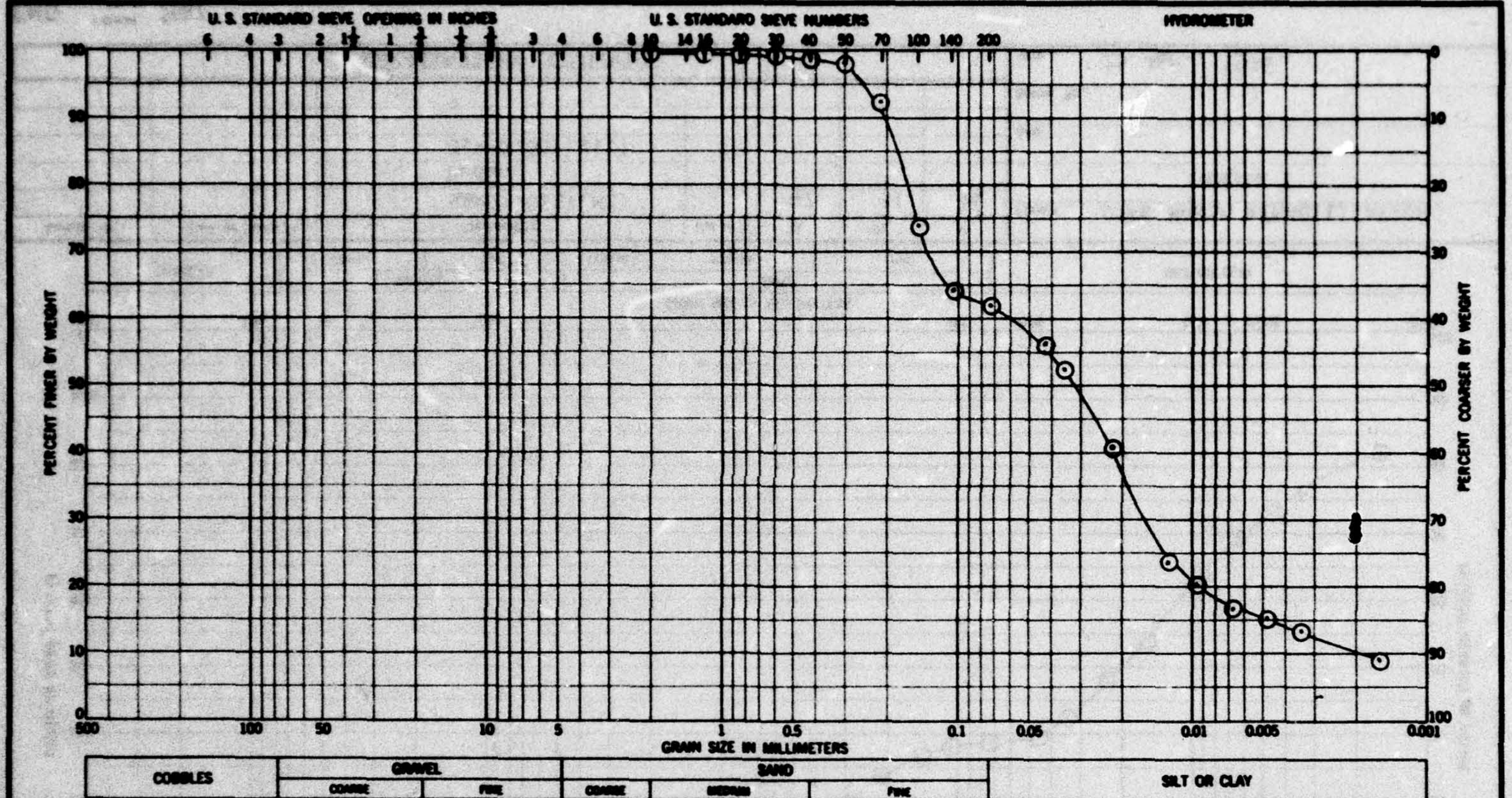

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
2		SANDY CLAY(CL) Brown Gs= 2.70(est)		43	26	17

Project: DYKE MARSH REHABILITATION
Sample 2

Area

Boring No.

Date: 26 Jan., 1976

GRADATION CURVES

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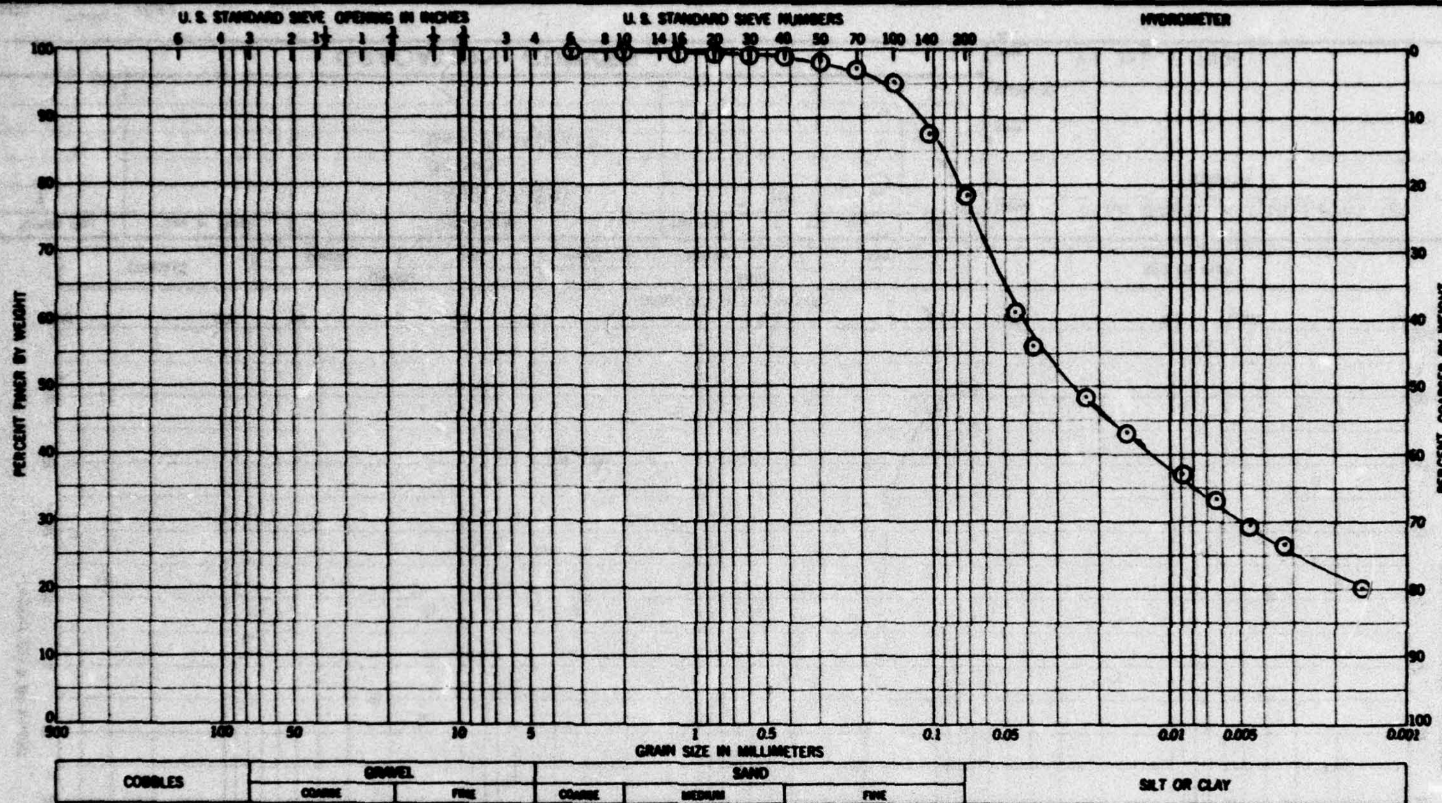

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
6		SANDY CLAY(CH)		70	33	37
		Dark Brown				
		Gs= 2.70(est)				

Project: DYKE MARSH REHABILITATION
Sample 6

Area:

Boring No.:

Date: 27 Jan., 1976

GRADATION CURVES

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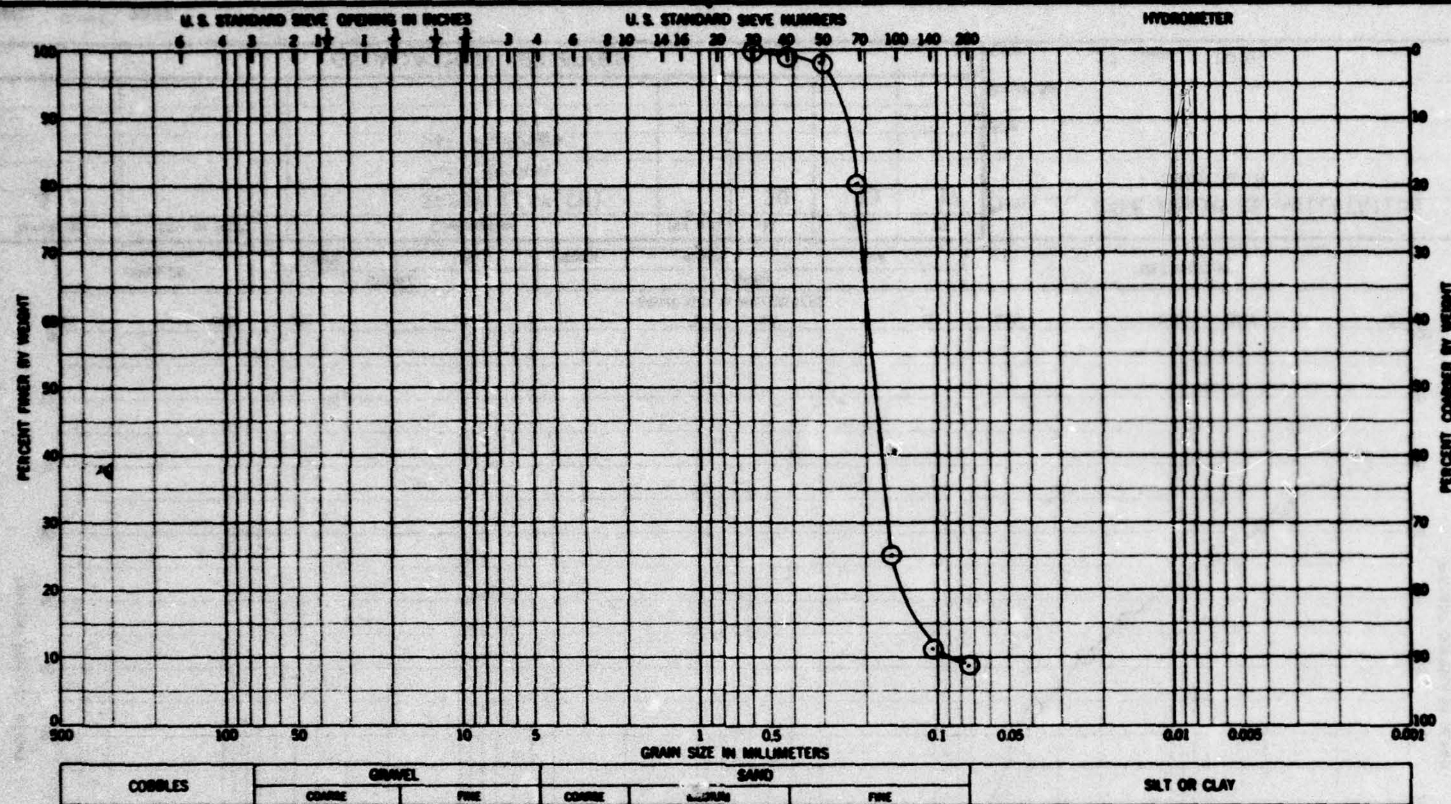


Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
7		SAND(SP-SM) Brown Gs= 2.65(est)		NP		

Project: DYKE MARSH REHABILITATION
Sample 7

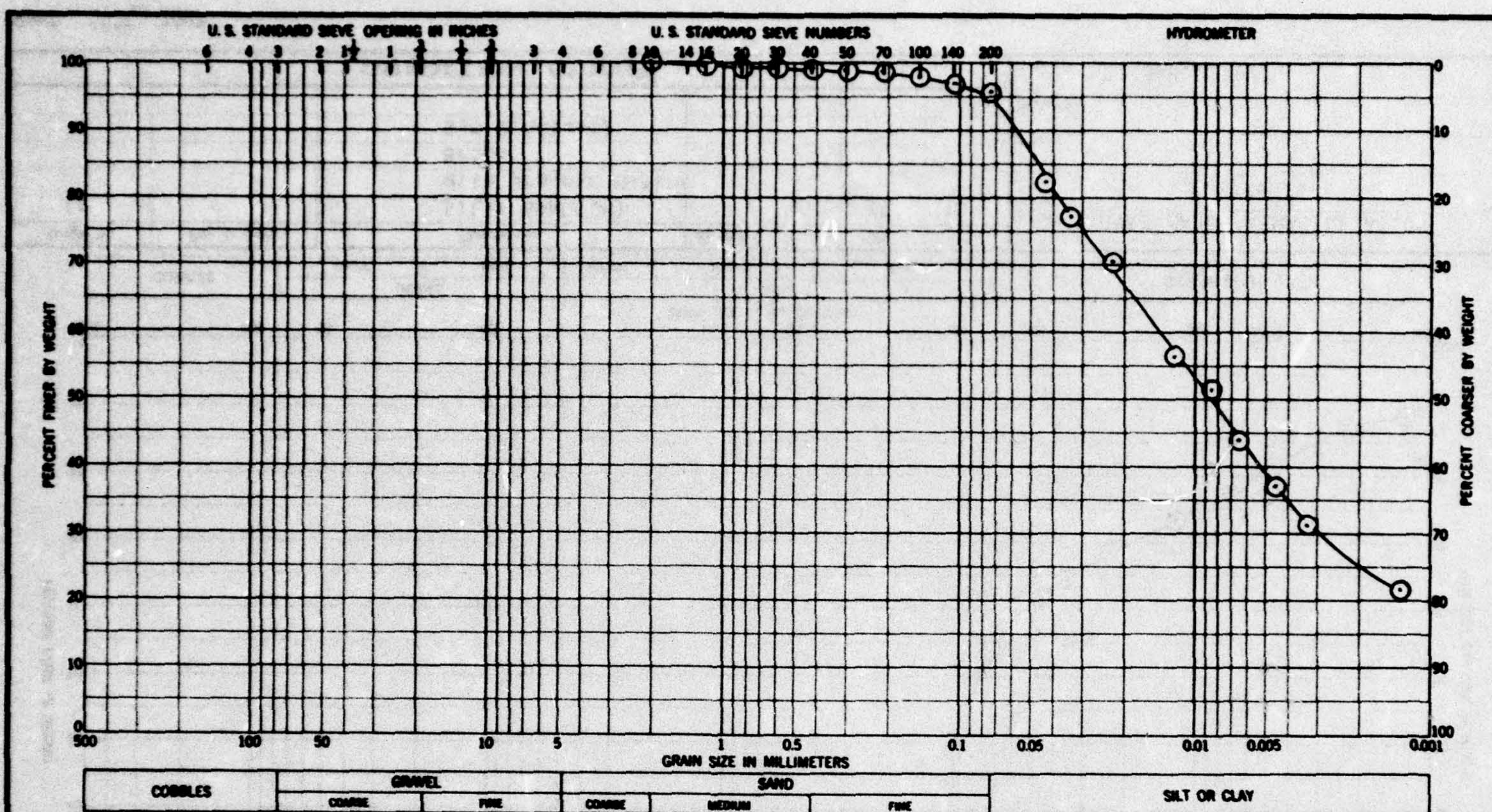
Area

Boring No.

Date: 27 Jan., 1976

GRADATION CURVES

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
8		CLAYEY SILT(MH)		94	44	50
		With Trace Sand				
		Brown				
		Brown				

Project: DYKE MARSH REHABILITATION
Sample 8

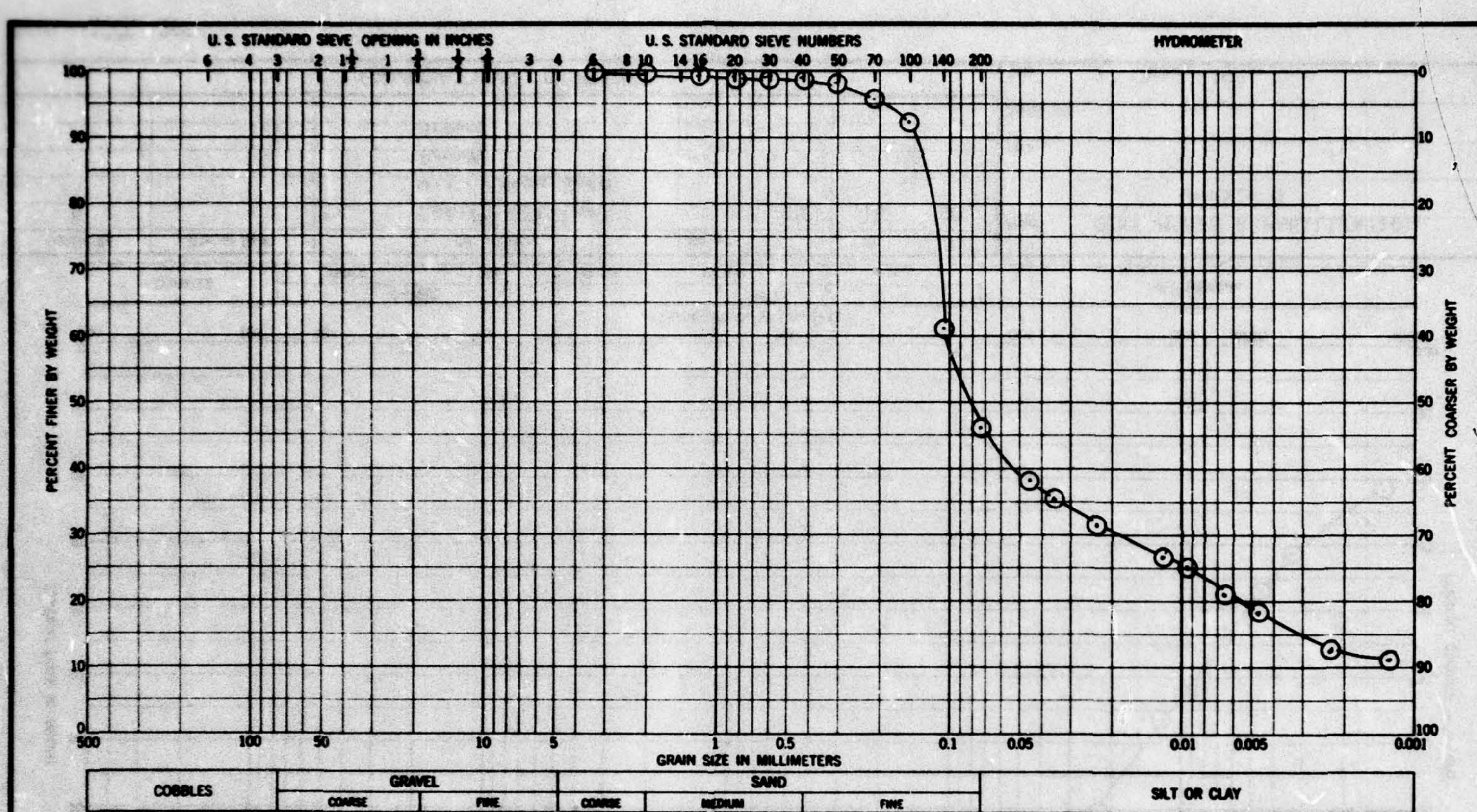
Area:

Boring No.:

Date: 27 Jan., 1976

GRADATION CURVES

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
11		SILTY SAND(SM)		45	35	10
		With Oragnic Matter				
		Brown				
		Gs= 2.66(est)				

Project: DYKE MARSH REHABILITATION

Sample 11

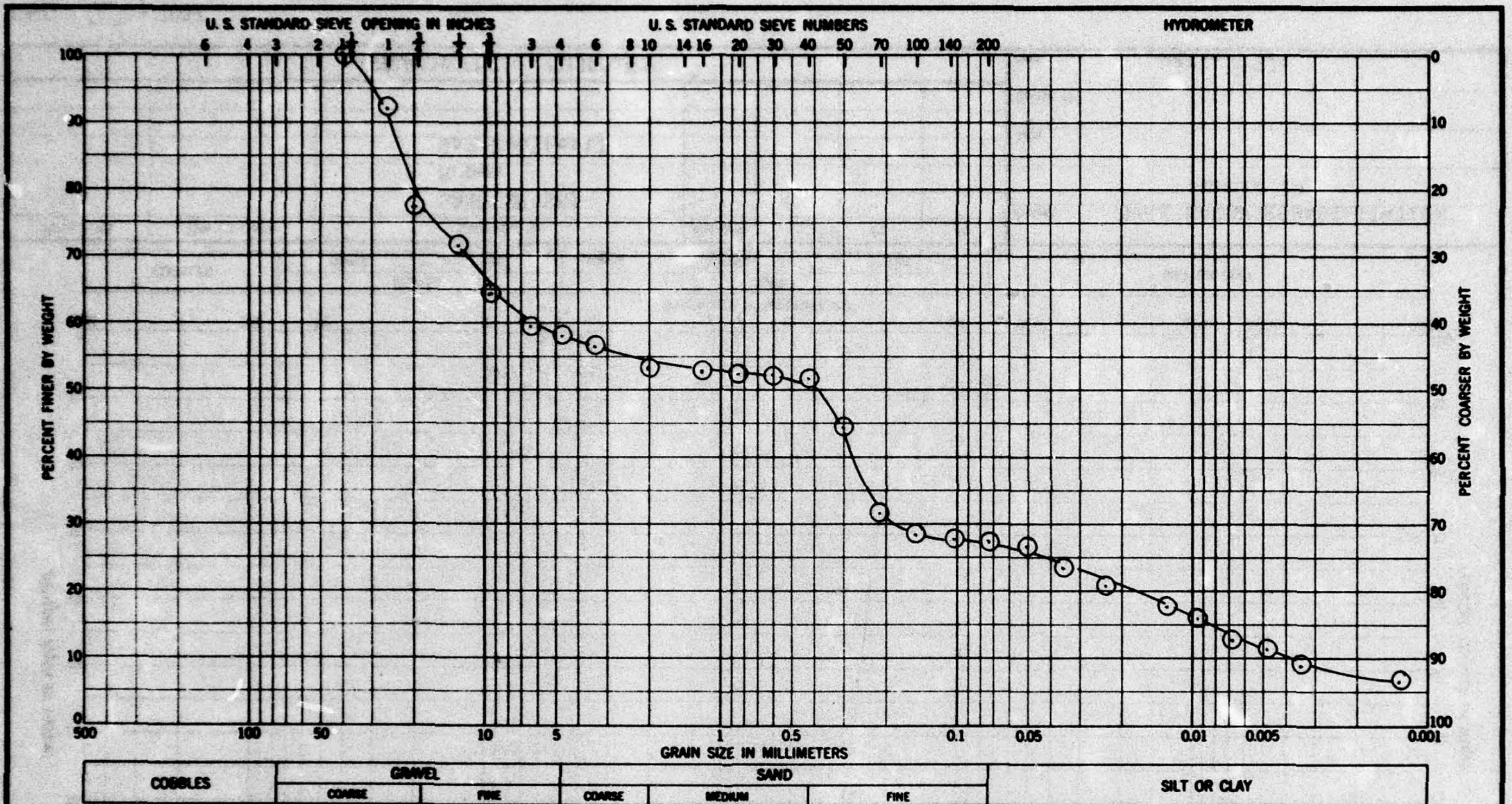
Area

Boring No.

Date: 27 Jan., 1976

GRADATION CURVES

ENG FORM 1 MAY 63 2087

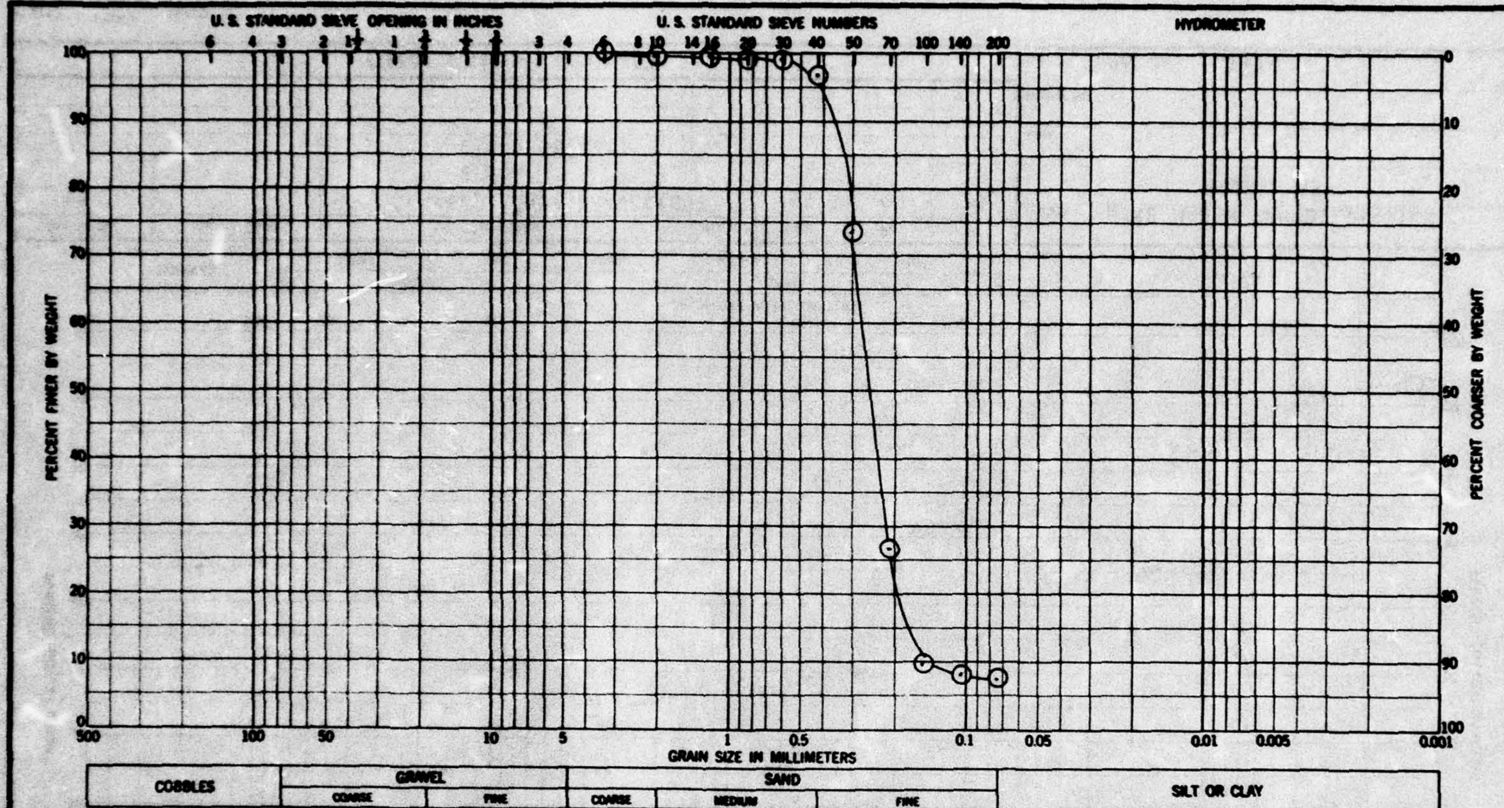


Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
13		CLAYEY, SANDY GRAVEL(GC)		55	27	28
		Brown				
		Gs= 2.66(est)				

Project	DYKE MARSH REHABILITATION Sample 13
Area	
Boring No.	
Date	26 Jan., 1976

GRADATION CURVES

ENG FORM 1 MAY 63 2087

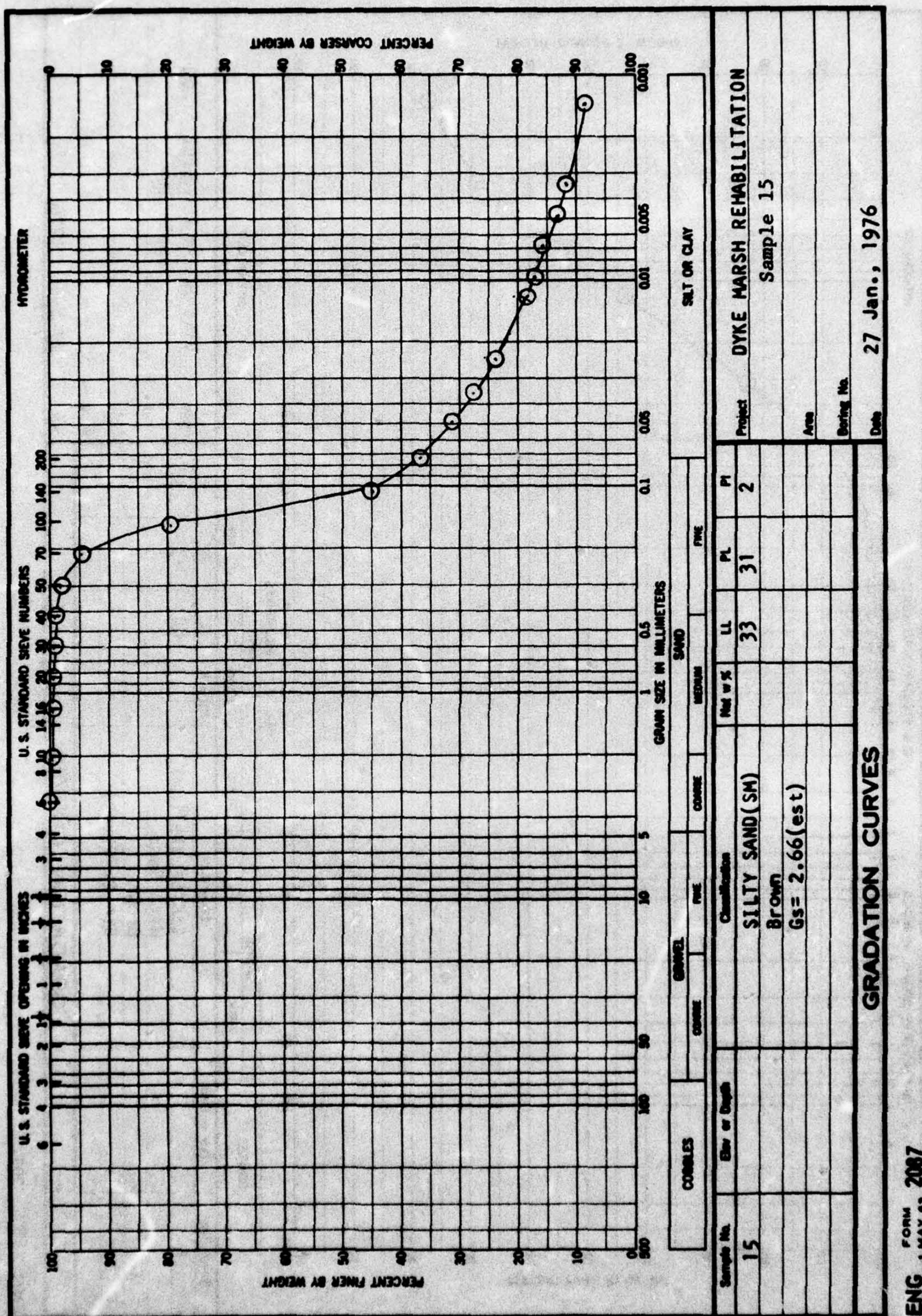


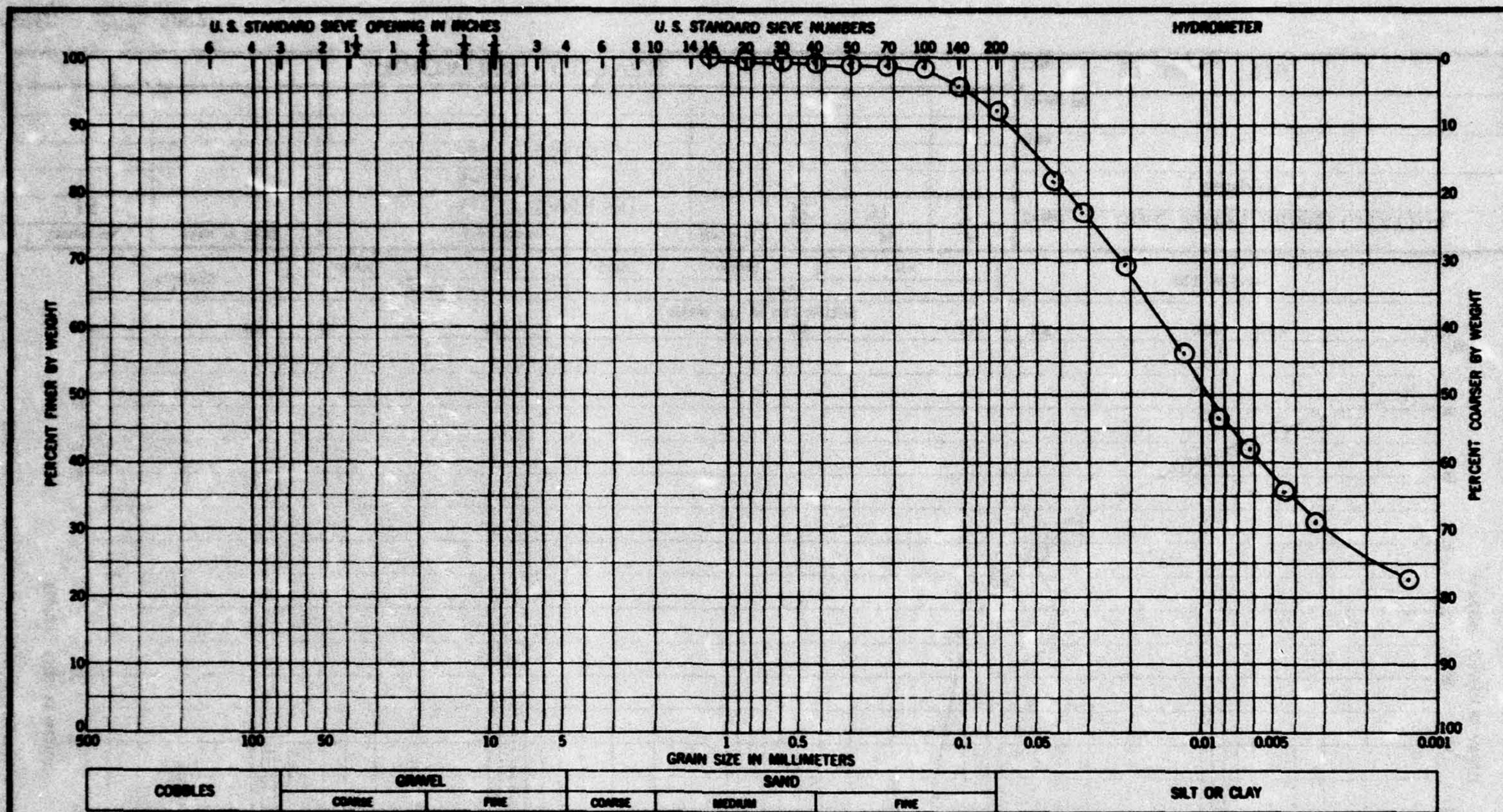
Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
14		SAND(SP-SM)		NP		
		Brown				
		Gs= 2.65(est)				

Project	DYKE MARSH REHABILITATION Sample 14
Area	
Boring No.	
Date	27 Jan., 1976

GRADATION CURVES

ENG FORM 1 MAY 63 2087


U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
15
Elev or Depth
Classification
SILTY SAND(SM)
Brown
Gs= 2.66(est)
Nat w %
LL
33
PL
31
PI
2
Project
DYKE MARSH REHABILITATION
Sample 15
Area
Boring No.
Date
27 Jan., 1976
GRADATION CURVES
ENG FORM 1 MAY 63 2087

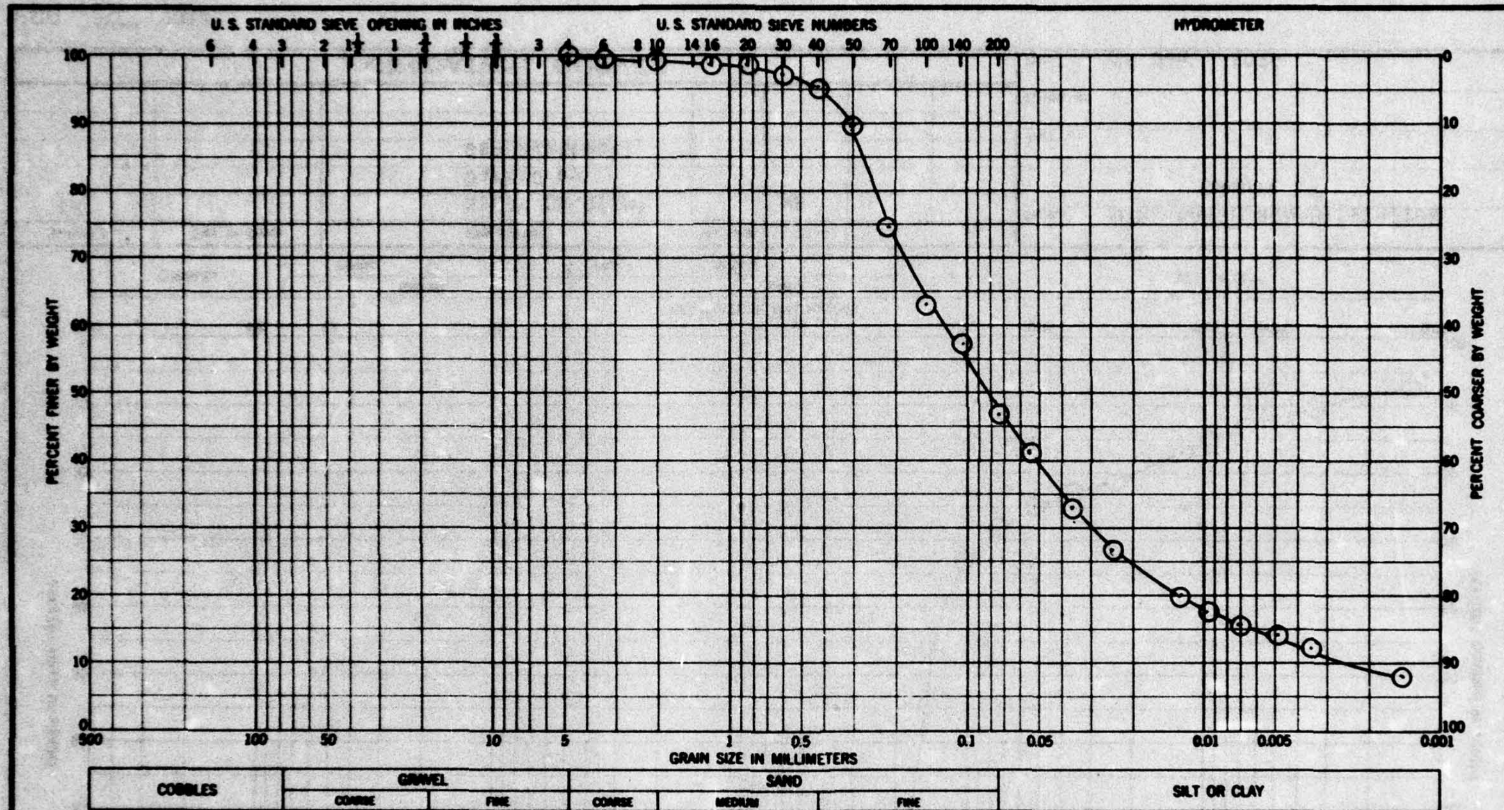


Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
16		CLAYEY SILT(MH) With Sand Brown Gs= 2.70(est)		80	43	37

Project	DYKE MARSH REHABILITATION Sample 16
Area	
Boring No.	
Date	27 Jan., 1976

GRADATION CURVES

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
17		SILTY SAND(SM) Brown Gs= 2.66(est)		34	32	2

Project DYKE MARSH REHABILITATION
Sample 17

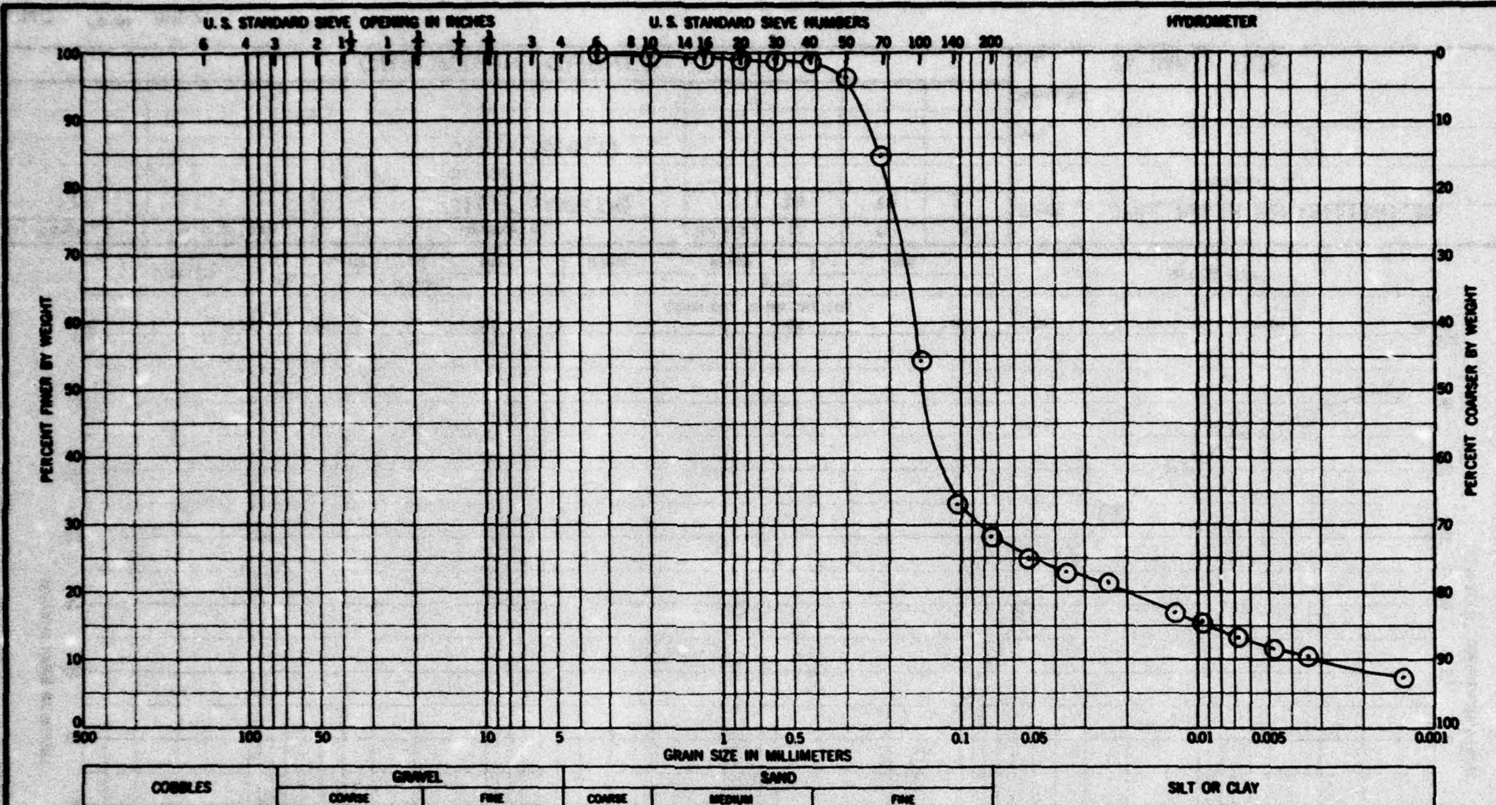
Area

Boring No.

Date 26 Jan., 1976

GRADATION CURVES

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
18		SILTY SAND(SM) Dark Gray Gs= 2.66(est)		NP		

Project: DYKE MARSH REHABILITATION
Sample 18

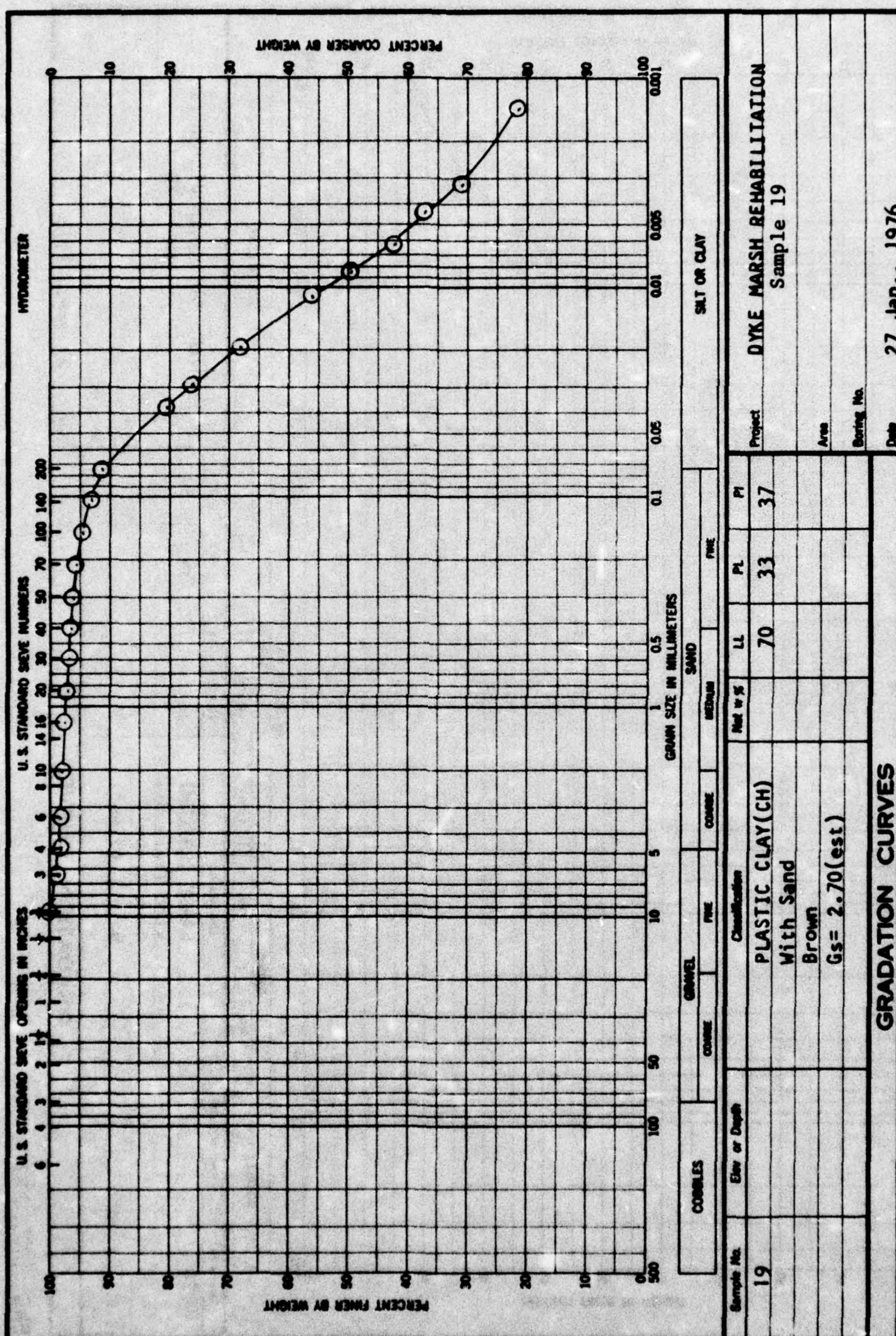
Area:

Boring No.:

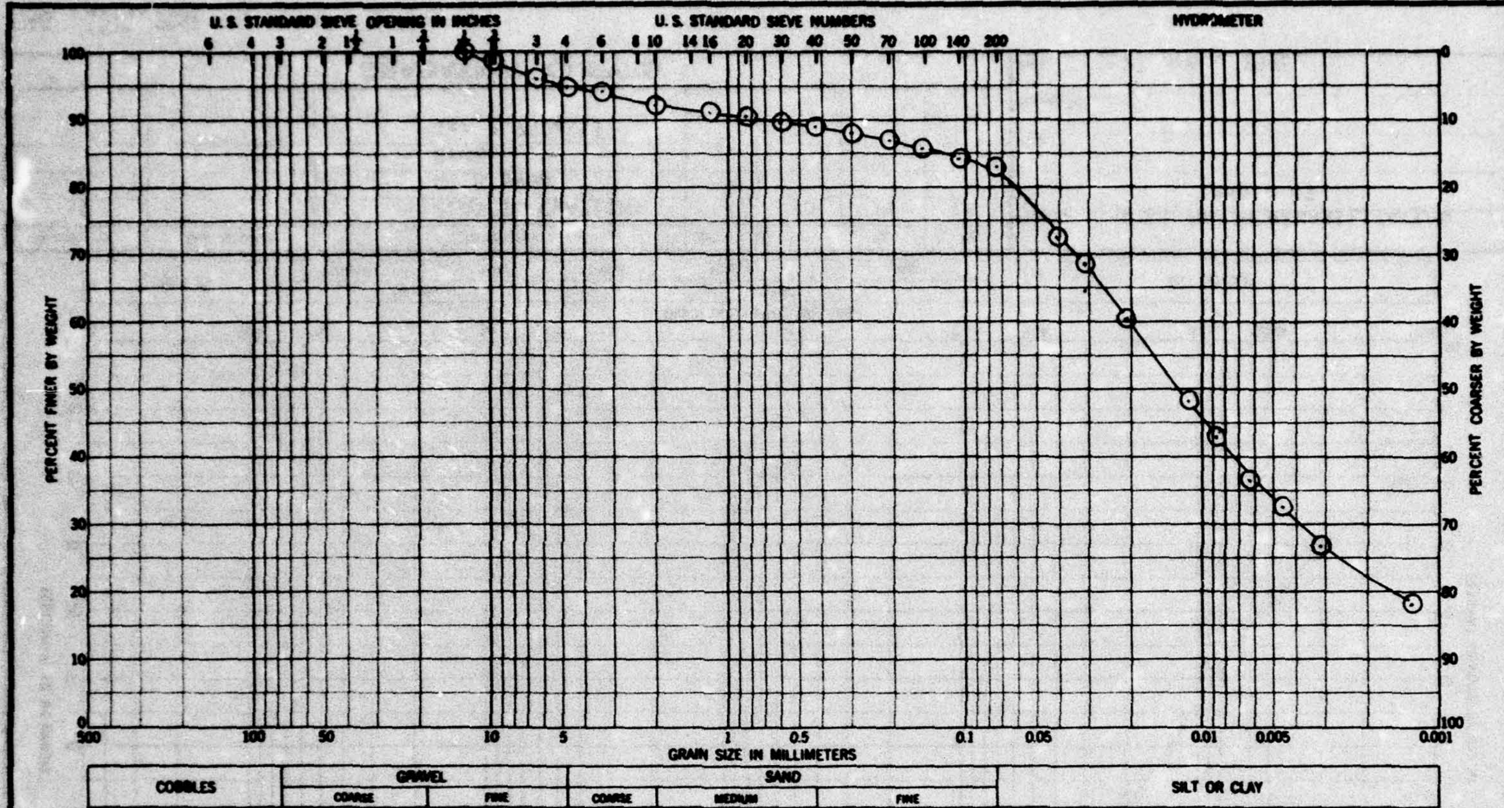
Date: 26 Jan., 1976

GRADATION CURVES

ENG FORM 1 MAY 63 2087



U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
19
PLASTIC CLAY(CH)
With Sand
Brown
Gs= 2.70(est)
70
33
37
Project
DYKE MARSH REHABILITATION
Sample 19
Area
Boring No.
Date
27 Jan., 1976
GRADATION CURVES
ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
20		SANDY CLAY(CH)		73	34	39
		With Trace Gravel				
		Dark Brown				
		Gs = 2.69(est)				

Project DYKE MARSH REHABILITATION
Sample 20

Area

Boring No.

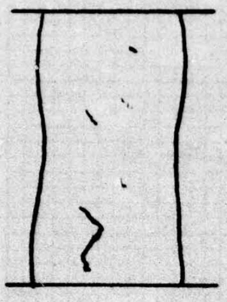
Date 27 Jan., 1976

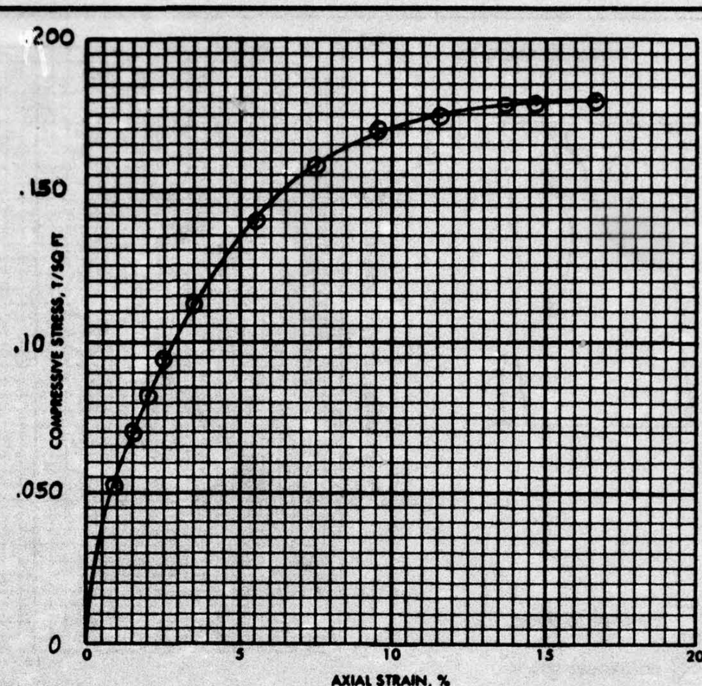
GRADATION CURVES

ENG FORM 1 MAY 63 2087

APPENDIX B: LABORATORY TEST RESULTS FOR FOUNDATION SOILS

FAILURE SKETCHES





☐ CONTROLLED STRESS

☒ CONTROLLED STRAIN

TEST NO.					
TYPE OF SPECIMEN		Undist.			
INITIAL — WATER CONTENT	w_o	64.8 %	%	%	%
INITIAL — VOID RATIO	e_o	1.679			
INITIAL — SATURATION	S_o	100.0 %	%	%	%
INITIAL — DRY DENSITY, LB/CU FT	γ_d	60.6			
TIME TO FAILURE, MIN	t_f	15.3			
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	0.179			
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	0.090			
SENSITIVITY RATIO	S_t	——			
INITIAL SPECIMEN DIAMETER, IN	D_o	2.78			
INITIAL SPECIMEN HEIGHT, IN.	H_o	5.95			

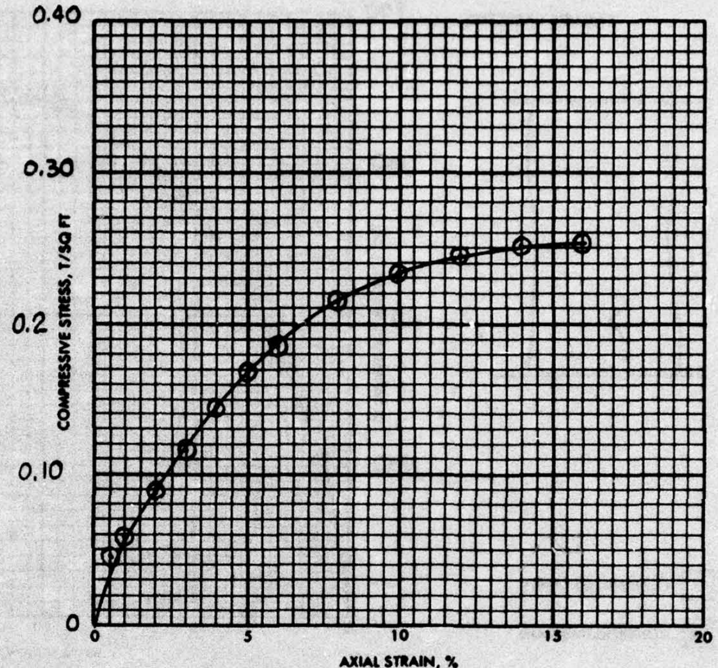
CLASSIFICATION Very moist, dark gray, firm, sandy, silty, clay (CH)

LL 80	PL 36	PI 44	G_s 2.60

REMARKS	PROJECT Dyke Marsh
	AREA Washington, D.C.
	BORING NO. DH-3 — SAMPLE NO. Shelby - B7
	DEPTH EL 19.0-21.0' — DATE Mar. 1976
	UNCONFINED COMPRESSION TEST REPORT

ENG FORM 1 JUN 66 3659 (EM 1110-2-1906) (TRANSLUCENT) GPO 1966 OF-216-966 PLATE XI-2

FAILURE SKETCHES



☐ CONTROLLED STRESS

☒ CONTROLLED STRAIN

TEST NO.						
TYPE OF SPECIMEN			Undist.			
INITIAL	WATER CONTENT	w_o	49.4 %	%	%	%
	VOID RATIO	e_o	1.313			
	SATURATION	S_o	99.7 %	%	%	%
	DRY DENSITY, LB/CU FT	γ_d	71.5			
TIME TO FAILURE, MIN		t_f	14.9			
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT		q_u	0.252			
UNDRAINED SHEAR STRENGTH, T/SQ FT		s_u	0.126			
SENSITIVITY RATIO		S_t	———			
INITIAL SPECIMEN DIAMETER, IN		D_o	2.79			
INITIAL SPECIMEN HEIGHT, IN.		H_o	6.09			

CLASSIFICATION Moist, dark gray, firm, silty, clay (CH)

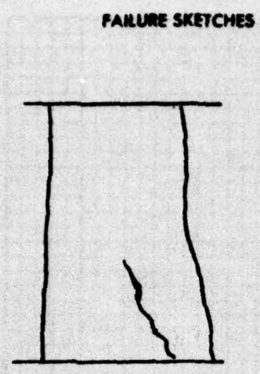
LL 62	PL 30	PI 32	G_s 2.65

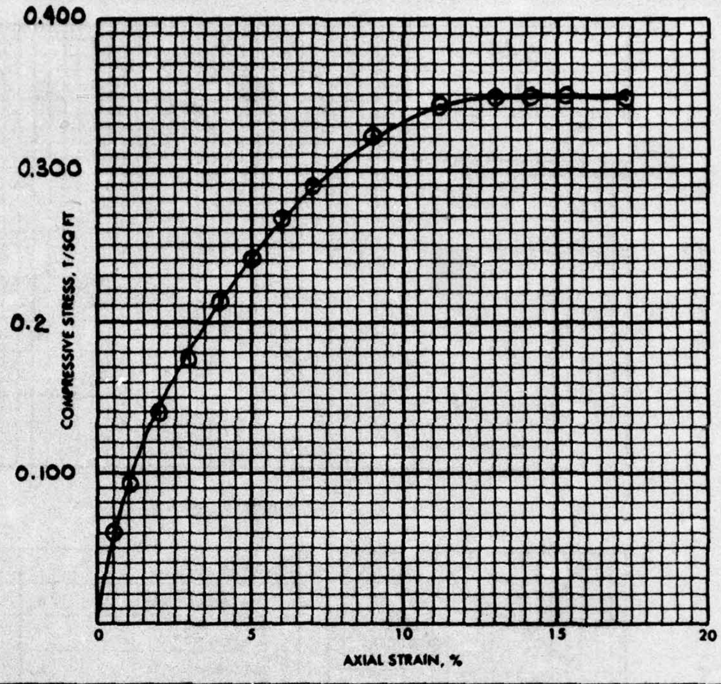
REMARKS

PROJECT	Dyke Marsh
AREA	Washington, D.C.
BORING NO. DH - 3	SAMPLE NO. Shelby - B8
DEPTH EL. 22.0 - 24.0'	DATE Mar. 1976

UNCONFINED COMPRESSION TEST REPORT

ENG FORM 1 JUN 65 3659 (EM 1110-2-1906) (TRANSLUCENT) GPO : 1966 OF—214-946 PLATE XI-2





☐ CONTROLLED STRESS

☒ CONTROLLED STRAIN

TEST NO.					
TYPE OF SPECIMEN		Undist.			
INITIAL: WATER CONTENT	w_o	76.1 %	%	%	%
INITIAL: VOID RATIO	e_o	2.026			
INITIAL: SATURATION	S_o	99.2 %	%	%	%
INITIAL: DRY DENSITY, LB/CU FT	γ_d	54.4			
TIME TO FAILURE, MIN	t_f	14.7			
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	0.349			
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	0.175			
SENSITIVITY RATIO	S_t	——			
INITIAL SPECIMEN DIAMETER, IN	D_o	2.81			
INITIAL SPECIMEN HEIGHT, IN.	H_o	5.90			

CLASSIFICATION Moist, dark gray, firm, sandy, silty, clay (CH)

LL 119 | PL 44 | PI 75 | G_s 2.64

REMARKS

PROJECT Dyke Marsh

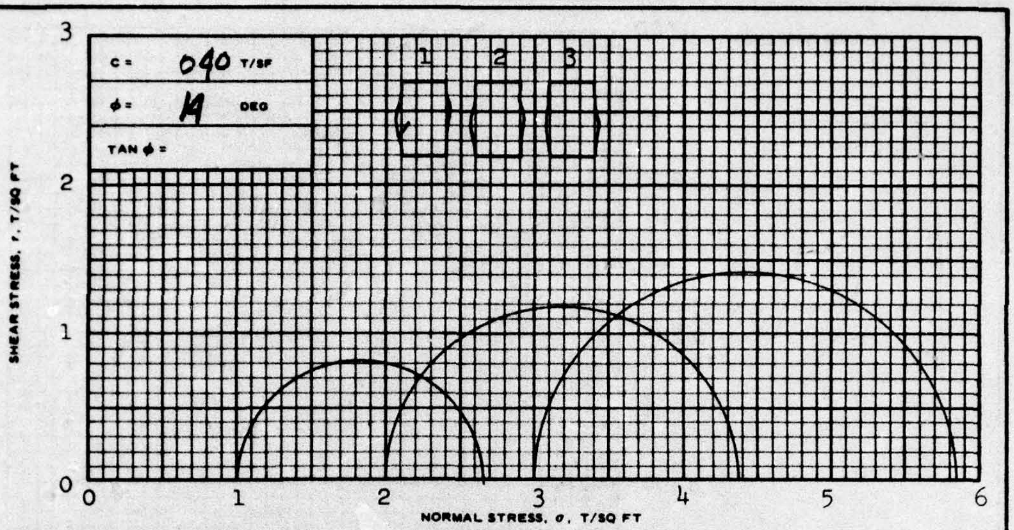
AREA Washington, D.C.

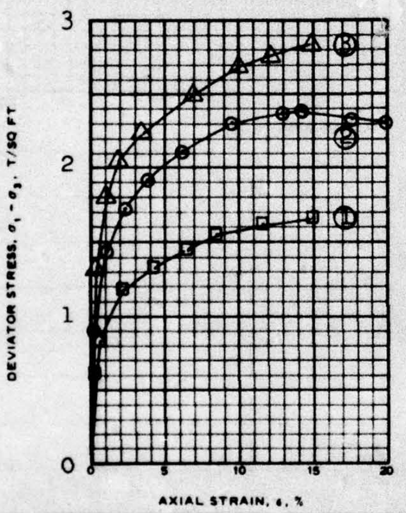
BORING NO. DH-3 | SAMPLE NO. Shelby - B9

DEPTH/EL 25.0 - 26.7' | DATE Mar. 1976

UNCONFINED COMPRESSION TEST REPORT

ENG FORM 3659 1 JUN 65 (EM 1110-2-1906) (TRANSLUCENT) GPO 1965 OF—214-946 PLATE XI-2





SPECIMEN NO.			1	2	3
INITIAL	WATER CONTENT, %	w_o	34.7	30.0	35.1
	DRY DENSITY LB/CU FT	γ_{d_o}	81.3	83.9	81.7
	SATURATION, %	S_o	87.5	80.5	89.5
	VOID RATIO	e_o	1.07	1.00	1.06
BEFORE SHEAR	WATER CONTENT, %	w_c	38.9	34.5	34.9
	DRY DENSITY LB/CU FT	γ_{d_c}	82.2	86.7	88.2
	SATURATION, %	S_c	100	99.0	100+
	VOID RATIO	e_c	1.04	0.937	0.905
	FINAL BACK PRESSURE, T/SQ FT	u_o	5.90	5.87	5.86
MINOR PRINCIPAL STRESS, T/SQ FT		σ_3	1.0	2.0	3.0
MAXIMUM DEVIATOR STRESS, T/SQ FT		$(\sigma_1 - \sigma_3)_{MAX}$	1.66	2.38	2.84
TIME TO $(\sigma_1 - \sigma_3)_{MAX}$, MIN		t_f	116	113	112
ULTIMATE DEVIATOR STRESS, T/SQ FT		$(\sigma_1 - \sigma_3)_{ULT}$			
INITIAL DIAMETER, IN.		D_o	1.33	1.35	1.35
INITIAL HEIGHT, IN.		H_o	2.84	2.89	2.76

CONTROLLED- Strain TEST

DESCRIPTION OF SPECIMENS SILT (ML), grayish brown

LL	PL	PI	G_s 2.69 (Est.)	TYPE OF SPECIMEN UNDISTURBED	TYPE OF TEST R

REMARKS:

See attached plot for effective values. Portion of sample allowed to drain before trimming

PROJECT DYKE MARSH

BORING NO. 2 SAMPLE NO. B-3

DEPTH/ELEV 6.6-8.6

LABORATORY USAEWES DATE 16 March 1976

Sheet 1 of 2

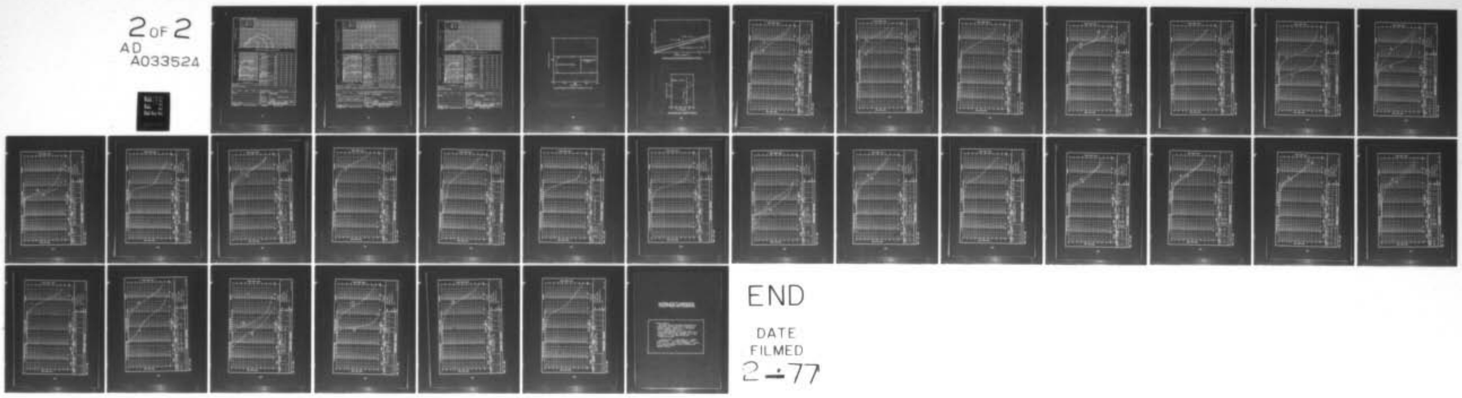
PJR TRIAXIAL COMPRESSION TEST REPORT

ENG FORM NO. 2089 REV JUNE 1970 PREVIOUS EDITION IS OBSOLETE TRANSLUCENT (EM 1110-2-1906)

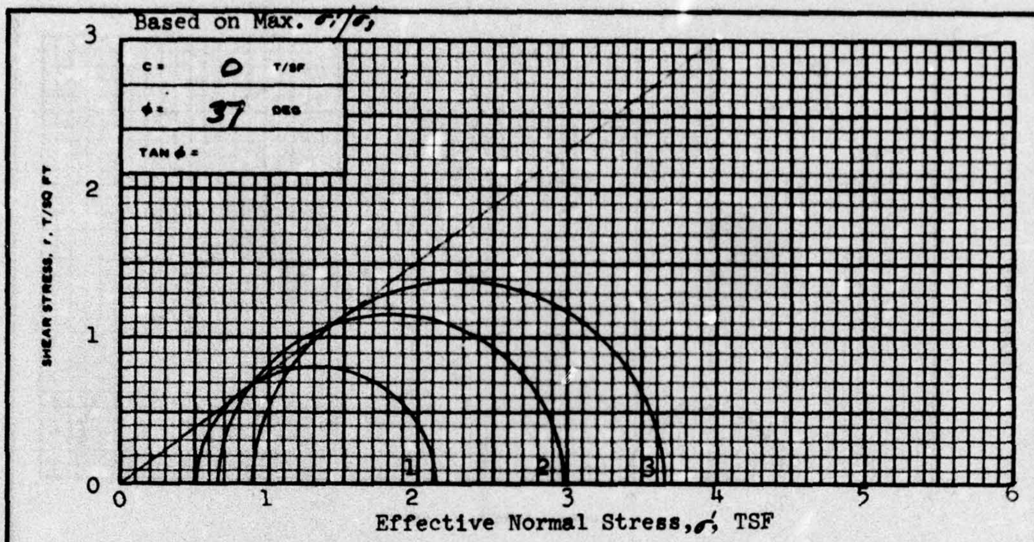
AD-A033 524 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 8/8
FEASIBILITY STUDY FOR DYKE MARSH DEMONSTRATION AREA, POTOMAC RI--ETC(U)
NOV 76 M R PALERMO, T W ZEIGLER

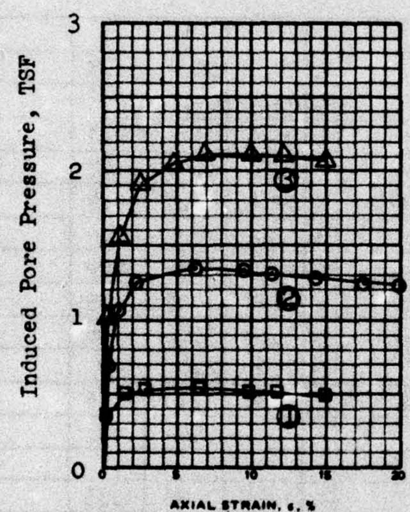
UNCLASSIFIED WES-TR-D-76-6 NL

2 OF 2
AD
A033524



END
DATE
FILMED
2-77





SPECIMEN NO.						
INITIAL	WATER CONTENT, %	w_o				
	DRY DENSITY LB/CU FT	γd_o				
	SATURATION, %	S_o				
	VOID RATIO	e_o				
BEFORE SHEAR	WATER CONTENT, %	w_c				
	DRY DENSITY LB/CU FT	γd_c				
	SATURATION, %	S_c				
	VOID RATIO	e_c				
	FINAL BACK PRESSURE, T/SQ FT	u_o				
MINOR PRINCIPAL STRESS, T/SQ FT		σ_3				
MAXIMUM DEVIATOR STRESS, T/SQ FT		$(\sigma_1 - \sigma_3)_{MAX}$				
TIME TO $(\sigma_1 - \sigma_3)_{MAX}$, MIN		t_f				
ULTIMATE DEVIATOR STRESS, T/SQ FT		$(\sigma_1 - \sigma_3)_{ULT}$				
INITIAL DIAMETER, IN.		D_o				
INITIAL HEIGHT, IN.		H_o				

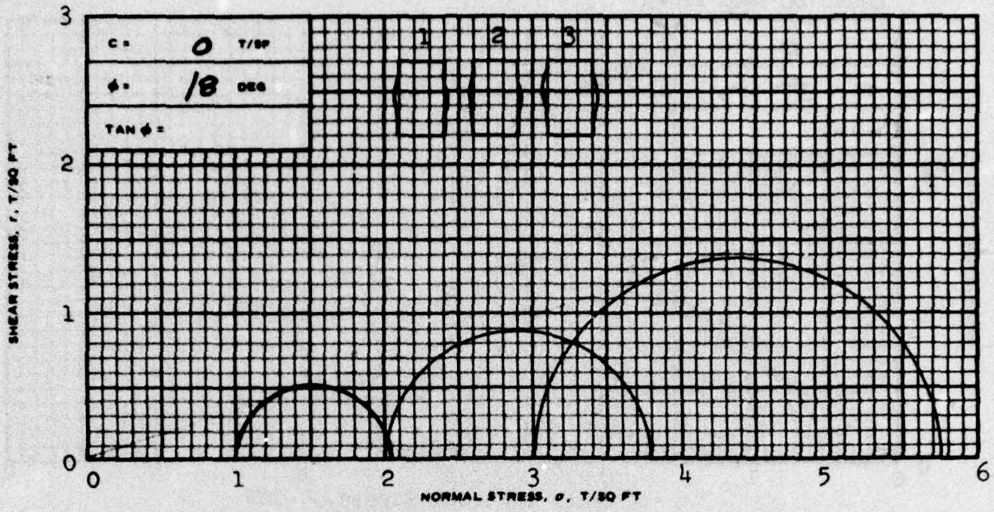
CONTROLLED- TEST

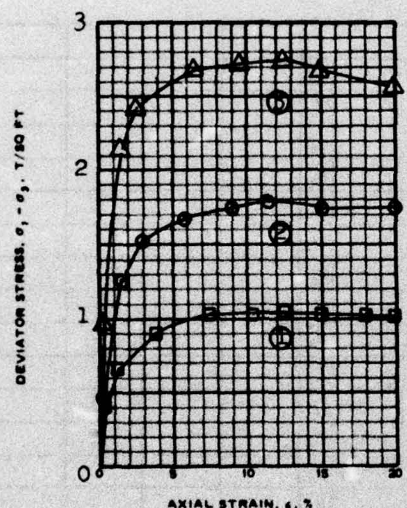
DESCRIPTION OF SPECIMENS

LL	PL	PI	G_s	TYPE OF SPECIMEN	TYPE OF TEST

REMARKS:	PROJECT	DYKE MARSH	
	BORING NO. 2	SAMPLE NO. B-3	
	DEPTH/ELEV 6.6-8.6		
	LABORATORY USAEWES	DATE 16 March 1976	
Sheet 2 of 2	TRIAXIAL COMPRESSION TEST REPORT		

ENG FORM NO. 2089 REV JUNE 1970 PREVIOUS EDITION IS OBSOLETE TRANSLUCENT (EM 1110-2-1906)





SPECIMEN NO.			1	2	3
INITIAL	WATER CONTENT, %	w_o	56.3	50.4	61.8
	DRY DENSITY LB/CU FT	γ_{d_o}	63.4	67.7	60.8
	SATURATION, %	S_o	93.8	93.7	96.3
	VOID RATIO	e_o	1.56	1.40	1.67
BEFORE SHEAR	WATER CONTENT, %	w_c	52.4	42.8	44.4
	DRY DENSITY LB/CU FT	γ_{d_c}	68.6	77.3	77.6
	SATURATION, %	S_c	99.7	100+	100+
	VOID RATIO	e_c	1.37	1.10	1.09
	FINAL BACK PRESSURE, T/SQ FT	u_o	5.88	5.86	5.88
MINOR PRINCIPAL STRESS, T/SQ FT		σ_3	1.0	2.0	3.0
MAXIMUM DEVIATOR STRESS, T/SQ FT		$(\sigma_1 - \sigma_3)_{max}$	1.05	1.79	2.75
TIME TO $(\sigma_1 - \sigma_3)_{max}$, MIN		t_f	104	90	61
ULTIMATE DEVIATOR STRESS, T/SQ FT		$(\sigma_1 - \sigma_3)_{ult}$			
INITIAL DIAMETER, IN.		D_o	1.31	1.33	1.33
INITIAL HEIGHT, IN.		H_o	2.86	2.82	2.80

CONTROLLED- Strain TEST

DESCRIPTION OF SPECIMENS ORGANIC SILT(OL), brownish gray; a few partly decayed roots

LL	PL	PI	G_s 2.60 (Est.	TYPE OF SPECIMEN UNDISTURBED	TYPE OF TEST R

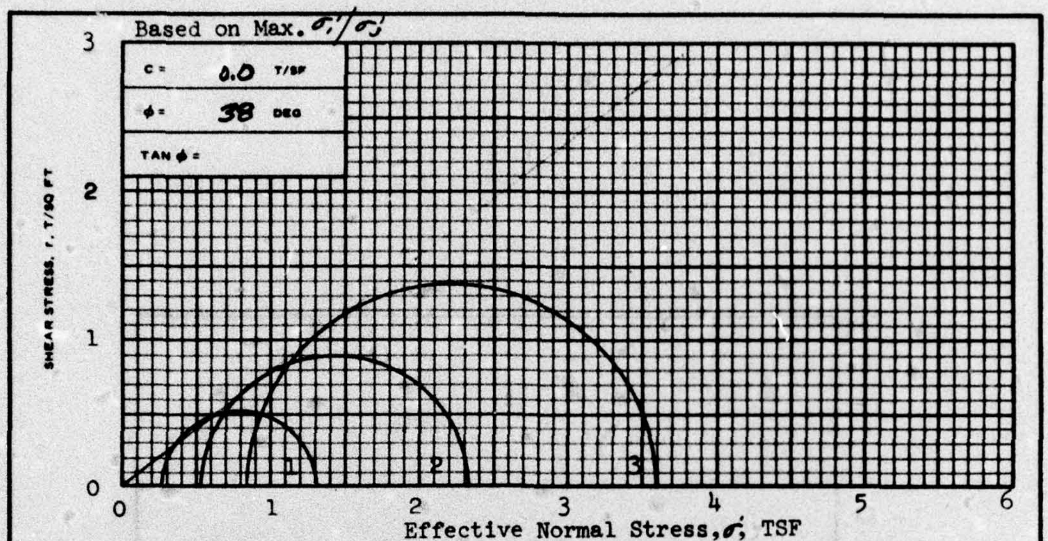
REMARKS:

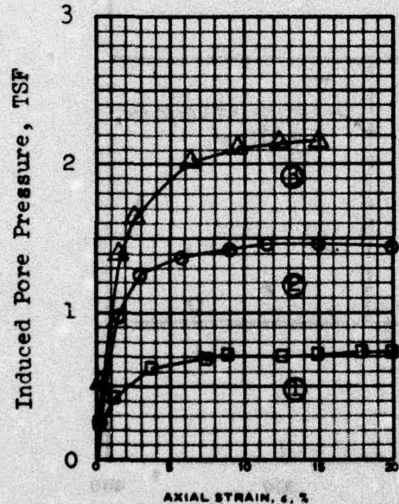
See attached plot for effective values. Portion of sample allowed to drain before trimming

Sheet 1 of 2

PROJECT	DYKE MARSH		
BORING NO.	3	SAMPLE NO.	B-3
DEPTH/ELEV	7.0-9.0		
LABORATORY	USAEWES	DATE	17 March 1976
PJR	TRIAXIAL COMPRESSION TEST REPORT		

ENG FORM NO. 2089 REV JUNE 1970 PREVIOUS EDITION IS OBSOLETE TRANSLUCENT (EM 1110-2-1906)





SPECIMEN NO.						
INITIAL	WATER CONTENT, %	w_o				
	DRY DENSITY LB/CU FT	γd_o				
	SATURATION, %	S_o				
	VOID RATIO	e_o				
BEFORE SHEAR	WATER CONTENT, %	w_c				
	DRY DENSITY LB/CU FT	γd_c				
	SATURATION, %	S_c				
	VOID RATIO	e_c				
	FINAL BACK PRESSURE, T/SQ FT	u_o				
MINOR PRINCIPAL STRESS, T/SQ FT		σ_3				
MAXIMUM DEVIATOR STRESS, T/SQ FT		$(\sigma_1 - \sigma_3)_{MAX}$				
TIME TO $(\sigma_1 - \sigma_3)_{MAX}$, MIN		t_f				
ULTIMATE DEVIATOR STRESS, T/SQ FT		$(\sigma_1 - \sigma_3)_{ULT}$				
INITIAL DIAMETER, IN.		D_o				
INITIAL HEIGHT, IN.		H_o				

CONTROLLED- TEST

DESCRIPTION OF SPECIMENS

LL	PL	PI	Gs	TYPE OF SPECIMEN	TYPE OF TEST

REMARKS:

PROJECT DYKE MARSH

BORING NO. 3 SAMPLE NO. B-3

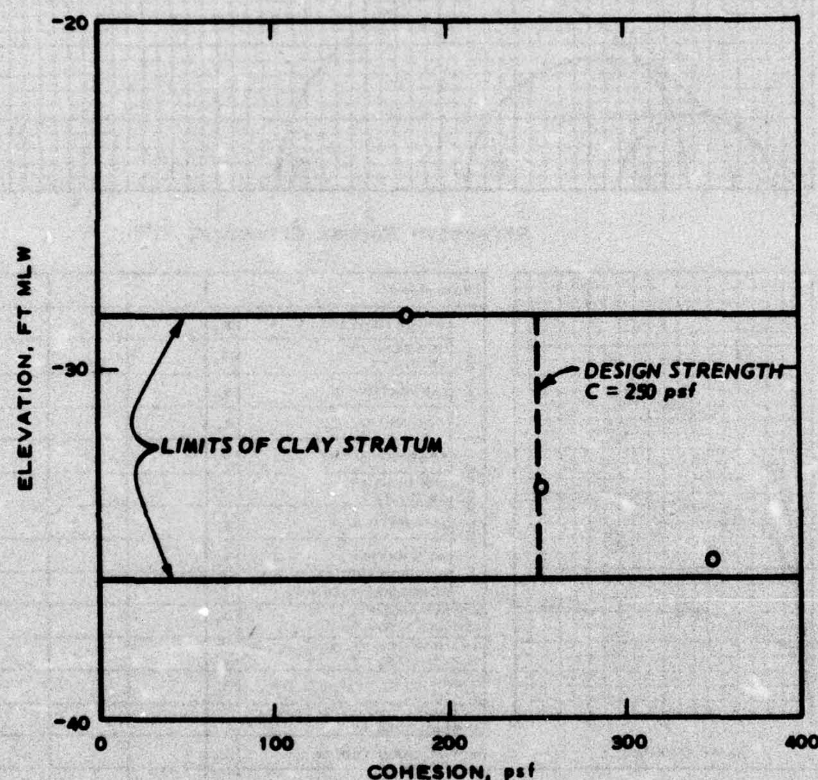
DEPTH/ELEV 7.0- 9.0

LABORATORY USAEWES DATE 17 March 1976

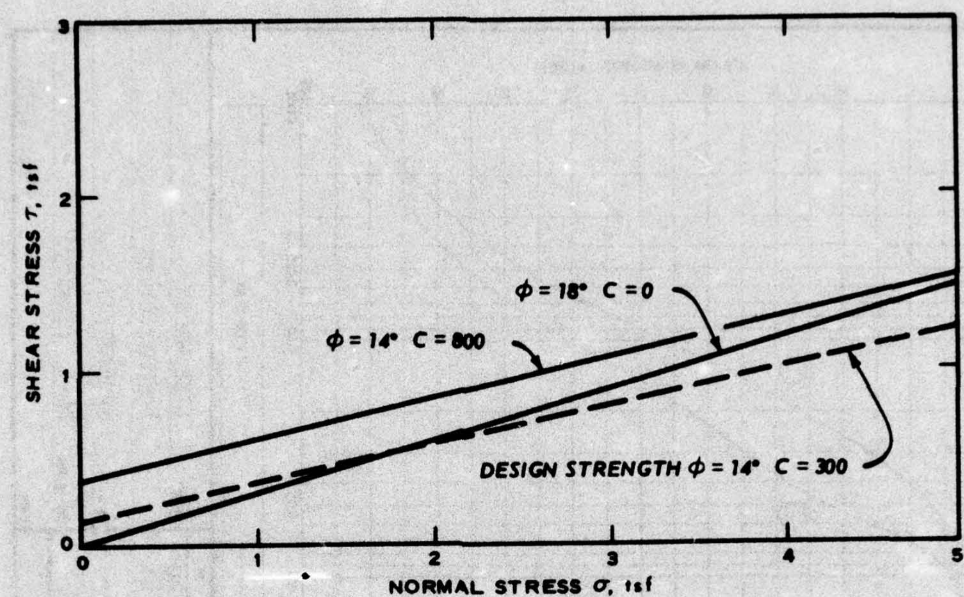
Sheet 2 of 2

TRIAXIAL COMPRESSION TEST REPORT

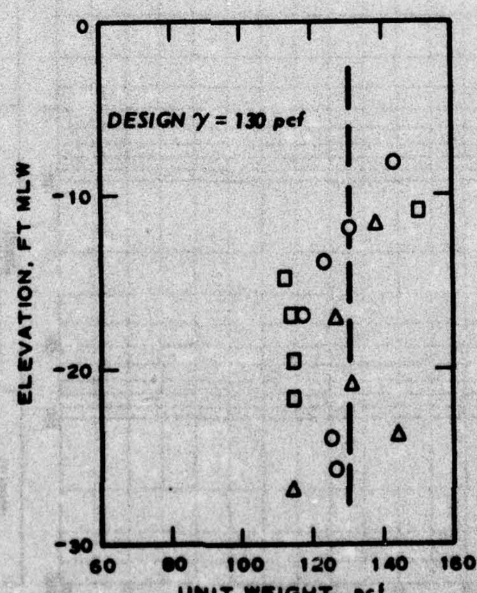
ENG FORM NO. 2089 REV JUNE 1970 PREVIOUS EDITION IS OBSOLETE TRANSLUCENT (EM 1110-2-1906)



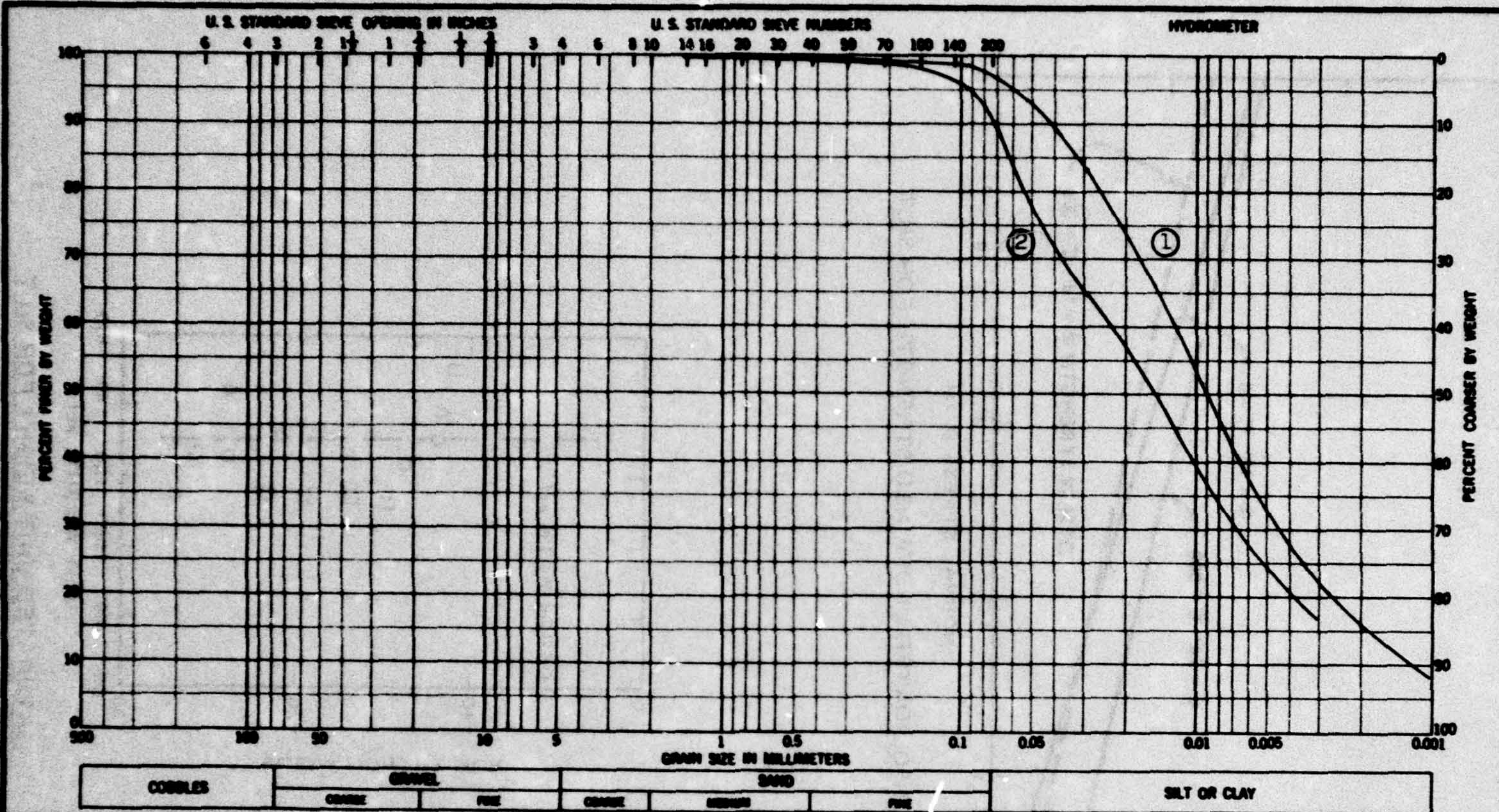
Unconsolidated undrained strength for clay



CONSOLIDATED UNDRAINED STRENGTH FOR SILT



SATURATED UNIT WEIGHT FOR SILT

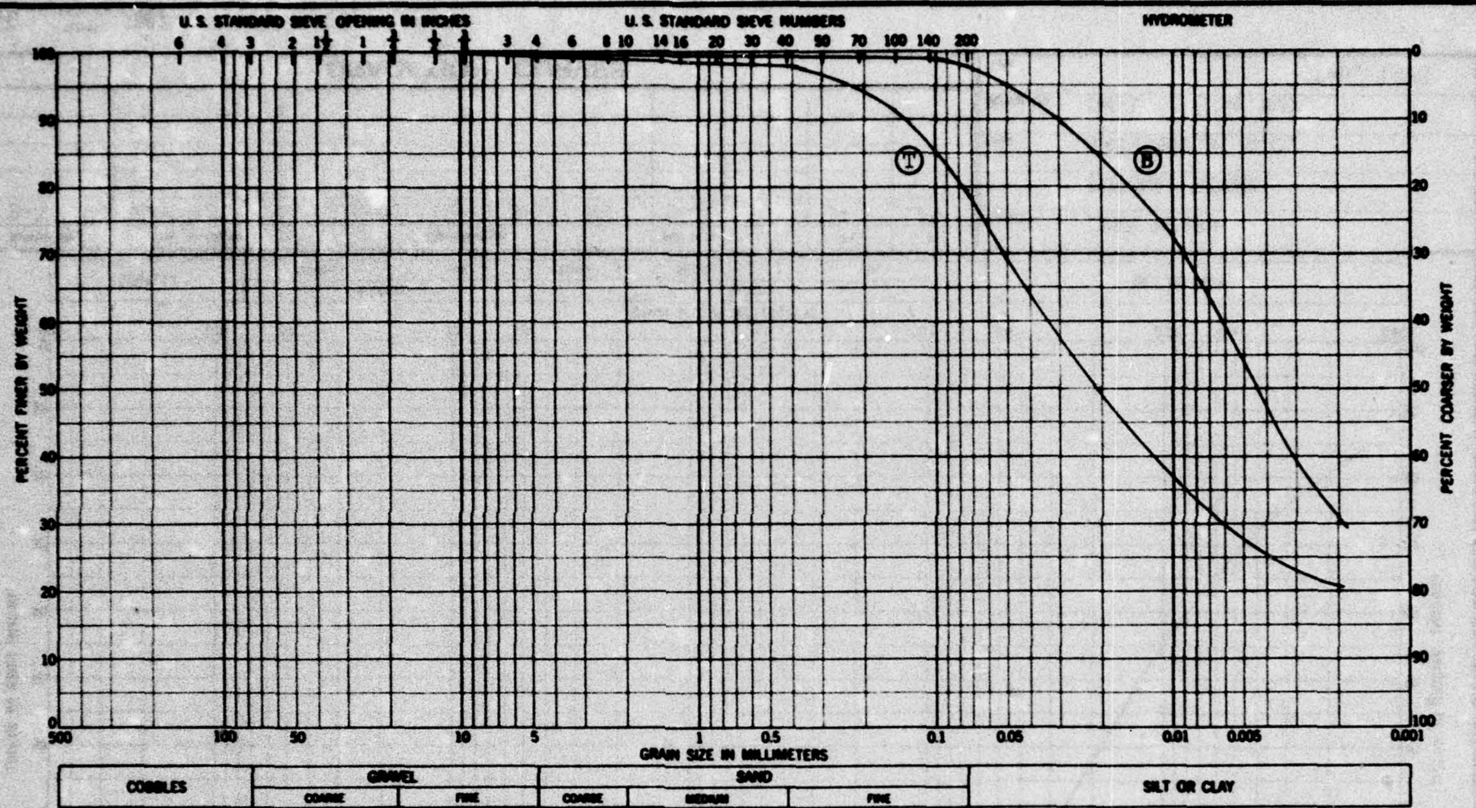


Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
B-1	1.0'-3.0'	Gray, Clayey Silt MH	96.8	83	43	40
B-2	4.0'-6.0	Gray, Sandy, Clayey Silt MH	73.9	78	37	41

Project: DYKE MARSH
POTOMAC RIVER
Area: WASHINGTON, D.C.
Boring No. DM-1 (Shelby)
Date: Feb. 1976

GRADATION CURVES

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
B-3(Top)	6.5'-8.5'	Gray, Sandy, Clayey Silt MH	63.8	62	30	32
B-3(Bot)	6.5'-8.5'	Gray, Sandy, Clayey Silt MH				

Project: DYKE MARSH
POTOMAC RIVER

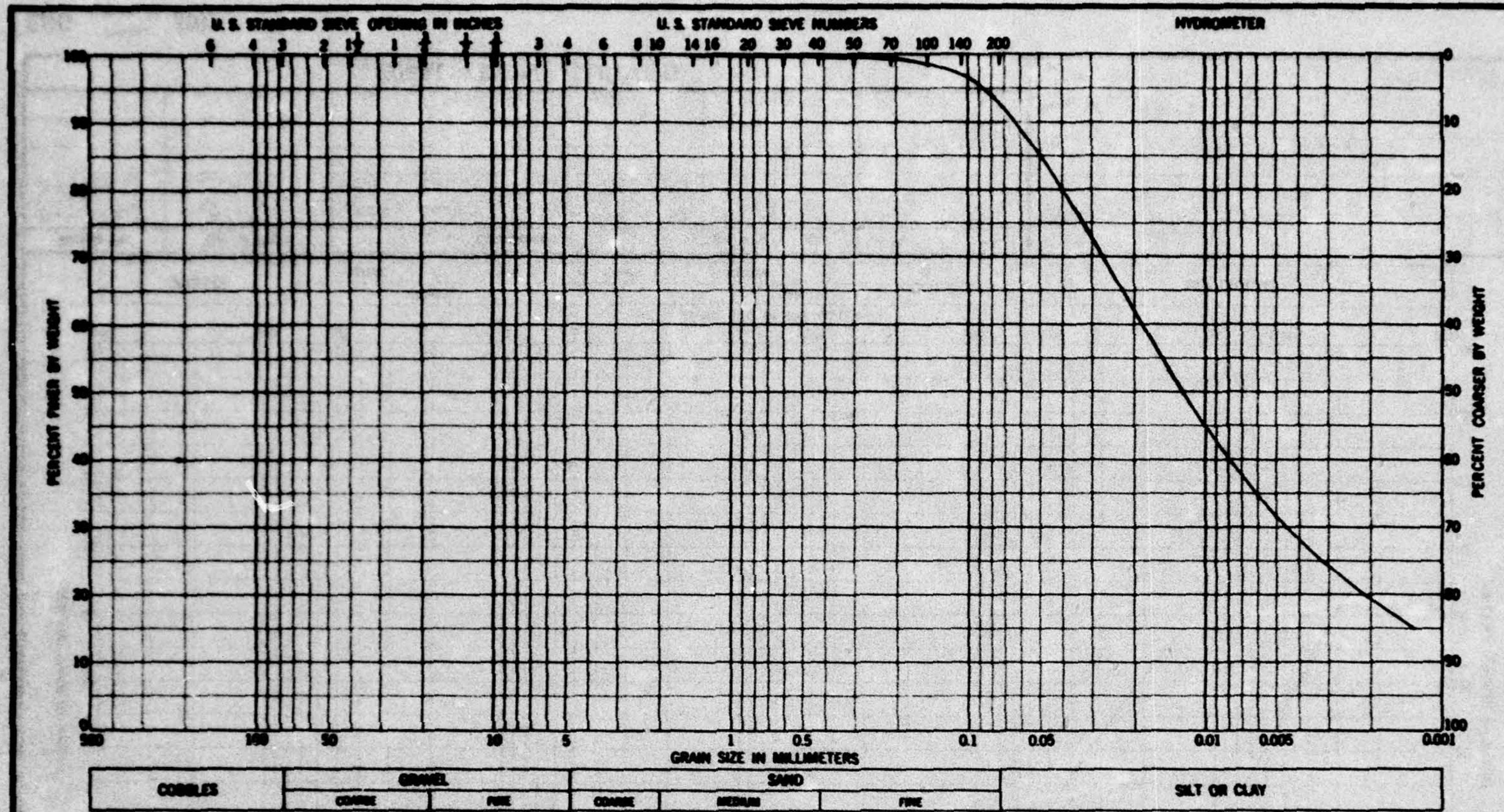
Area: WASHINGTON, D.C.

Boring No. DM-1 (Shelby)

Date: Feb. 1976

GRADATION CURVES

ENG FORM 1 MAY 63 2087



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
B-4	9.0'-10.7'	Gray, Clayey Silt MH	56.0	59	34	25

Project DYKE MARSH

POTOMAC RIVER

Area WASHINGTON, D.C.

Boring No. DM-1 (Shelby)

Date Feb. 1976

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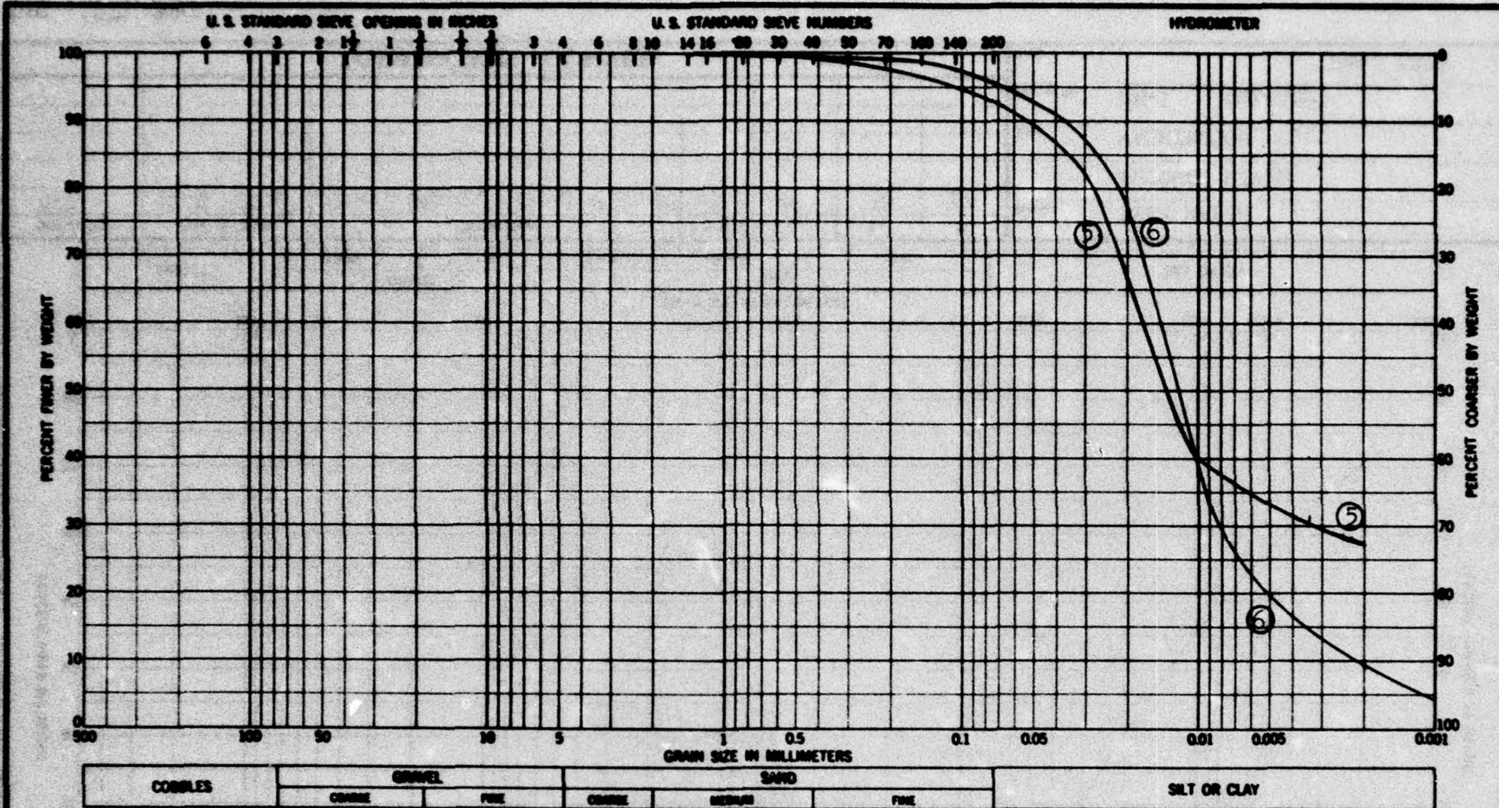

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
B-5	13.5'-15.5'	Gray, Clayey Silt MH	77.5	89	41	48
B-6	16.0'-18.0'	Gray, Clayey Silt MH	68.4	55	32	23

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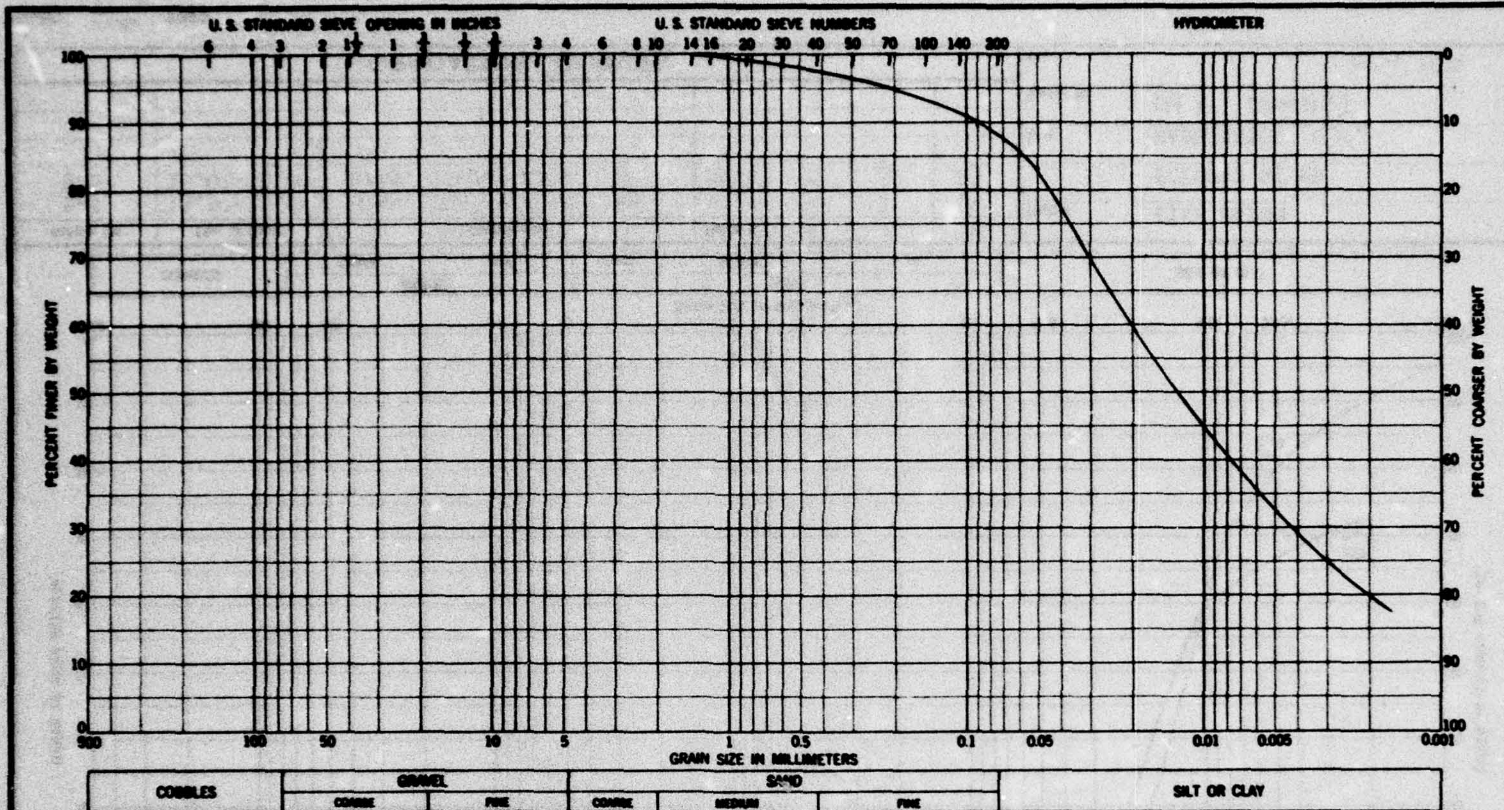

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
B-7	18.0'-20.0'	Gray, Sandy, Clayey Silt MH	68.3	75	38	37

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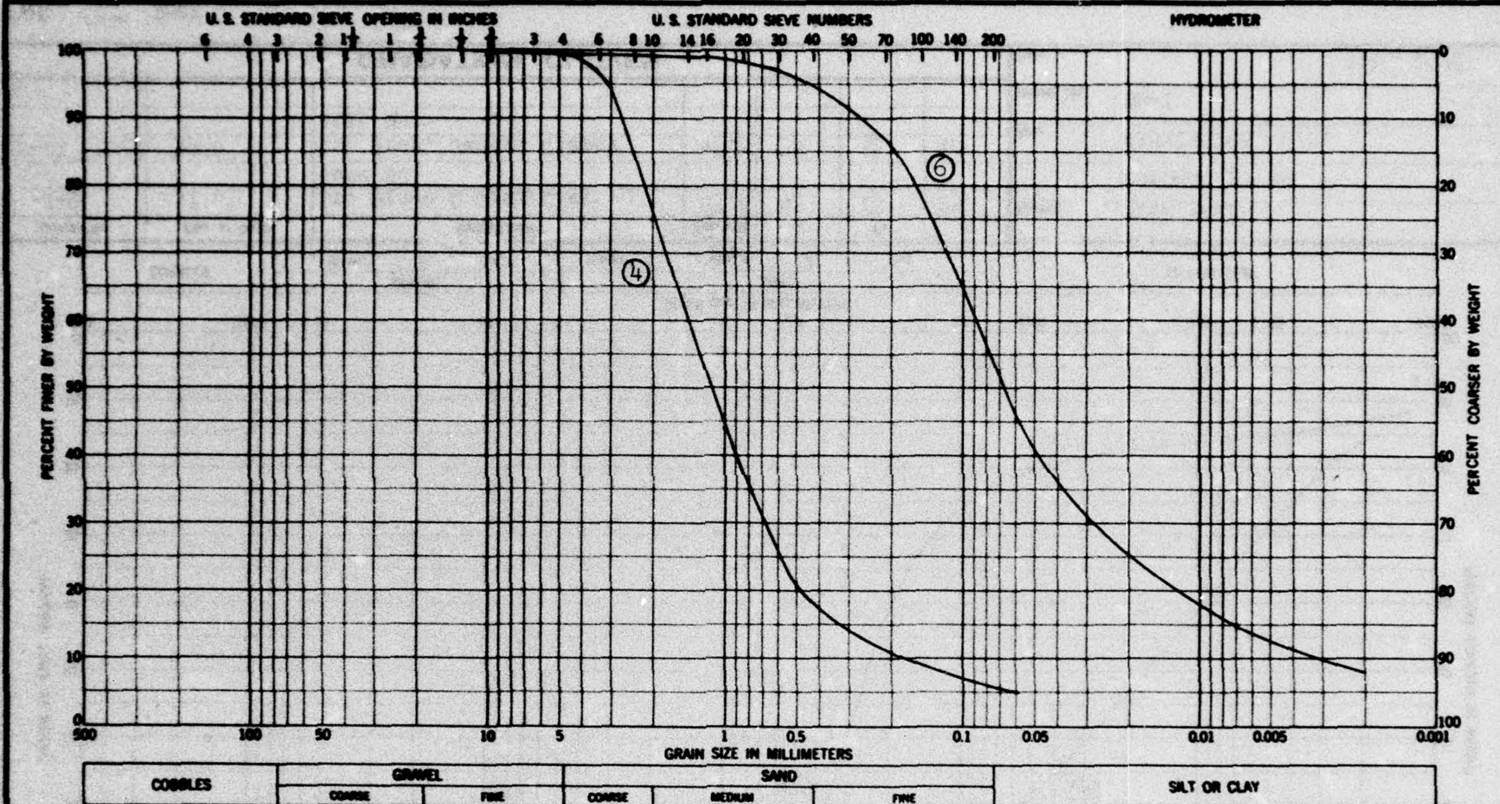

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
J-4	27'5"	Light Brown, Silty Sand SW-SM	14.1	-	-	-
J-6	31'6"	Brown, Sandy Silt ML	34.3		NP	

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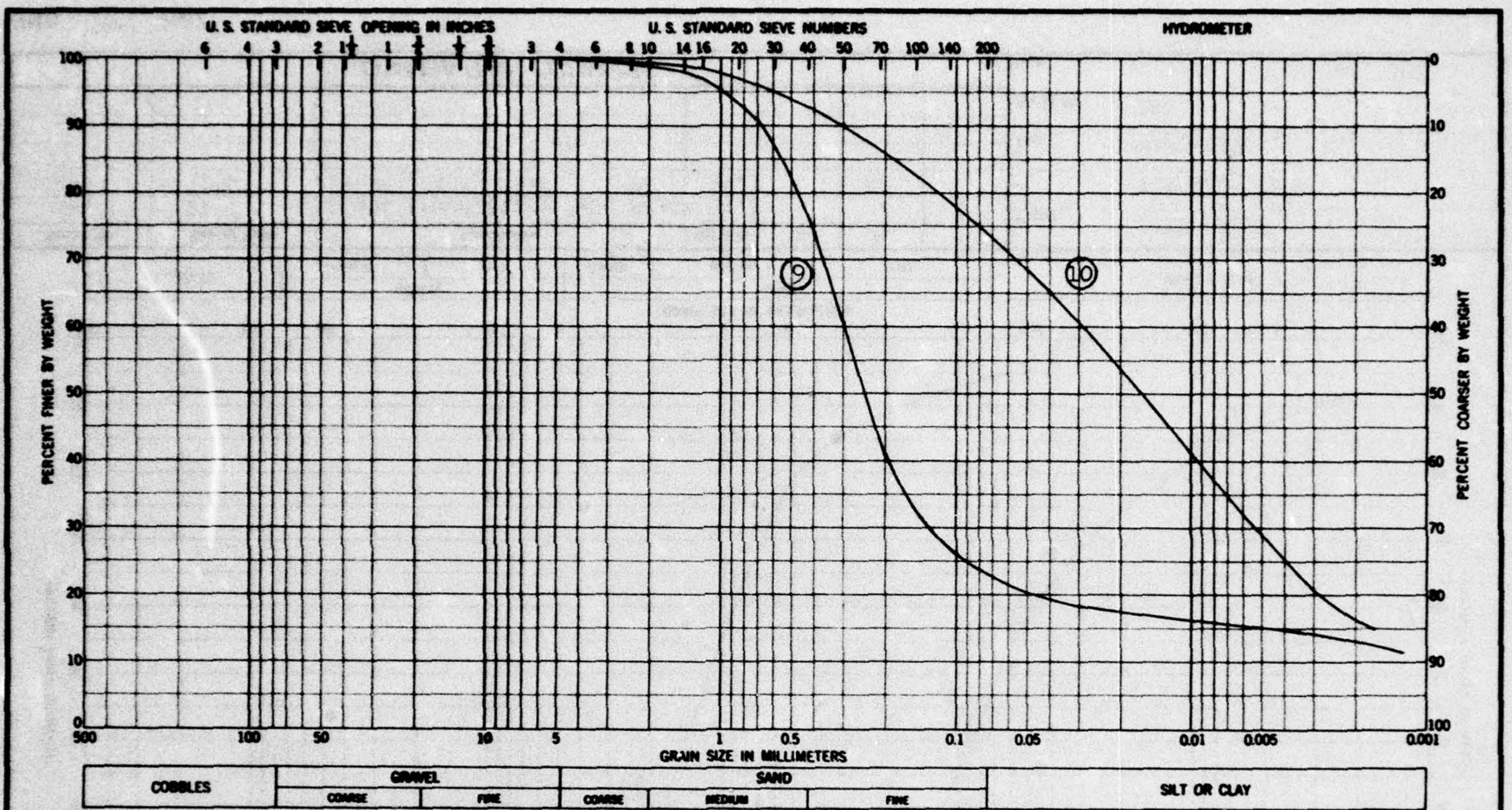

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
J-9	37'6"	Lt. Brown & Gray, Clayey Sand SC	23.6	43	18	25
J-10 (Top)	39'6"	Lt. Gray, Sandy, Clayey Silt MH	43.5	78	38	40

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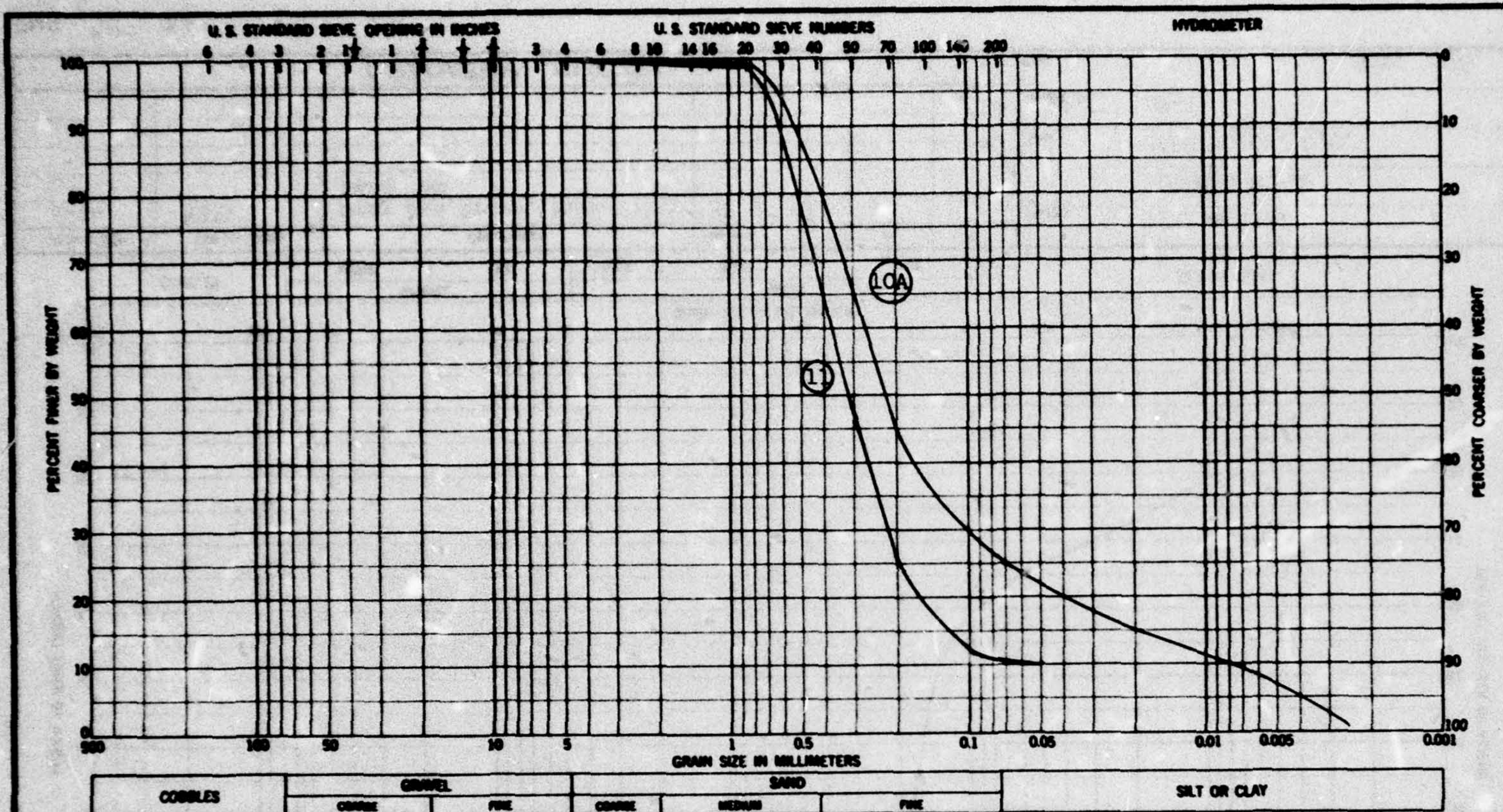

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
J-10A(Bot)	39'6"	Light Gray, Clayey Sand SC	23.5	65	22	43
J-11	41'6"	Light Brown, Silty Sand SW-SM	23.0	-	-	-

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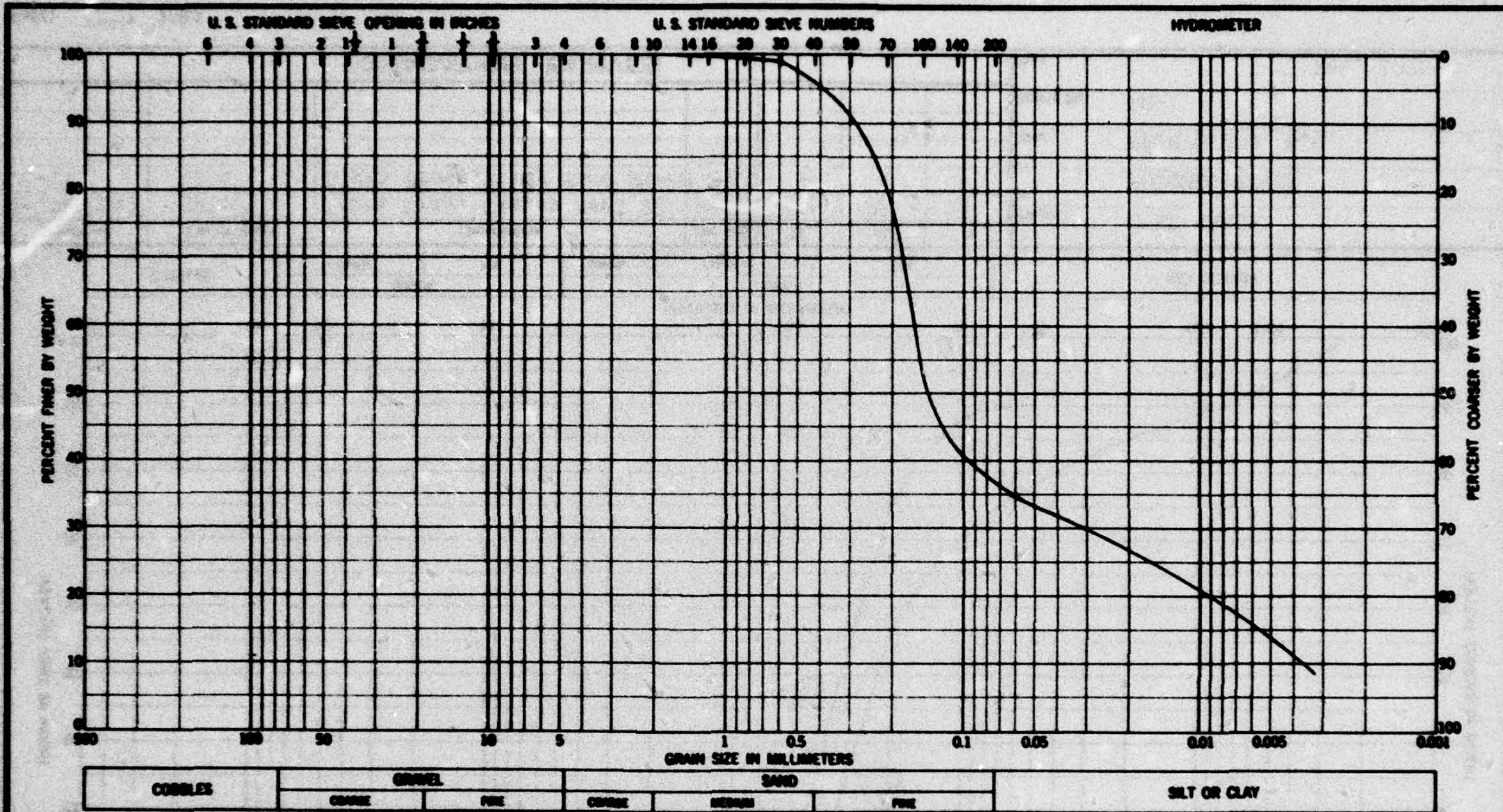

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
J-14	48'6"	Gray and Brown, Firm Silty Sand SM	32.9	58	37	21

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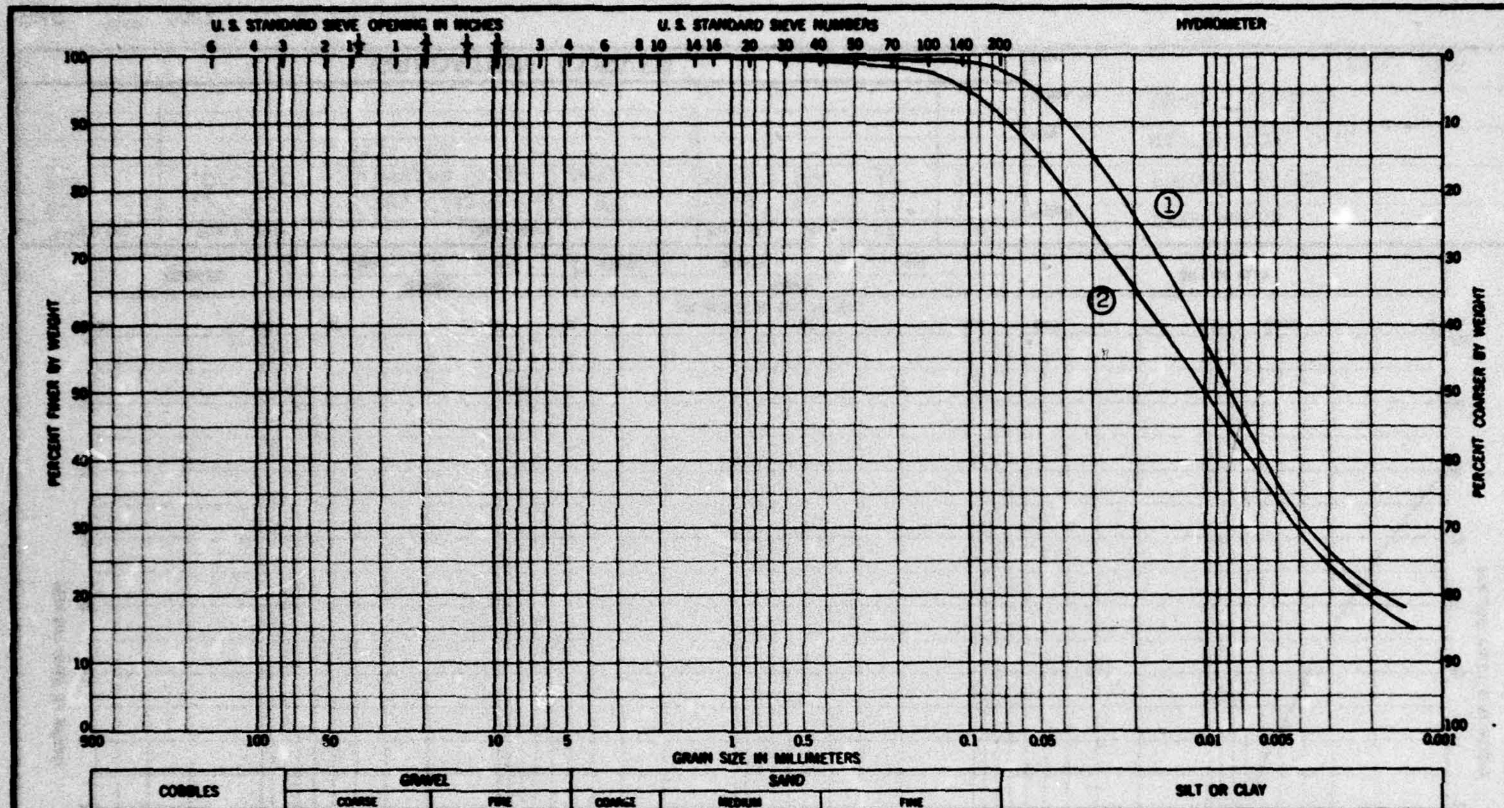

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
B-1 (Bot)	1.0'-3.0'	Brownish gray, Clayey Silt MH	98.6	88	39	49
B-2 (Bot)	4.0'-6.0'	Gray, Clayey Silt MH	48.8	58	33	25

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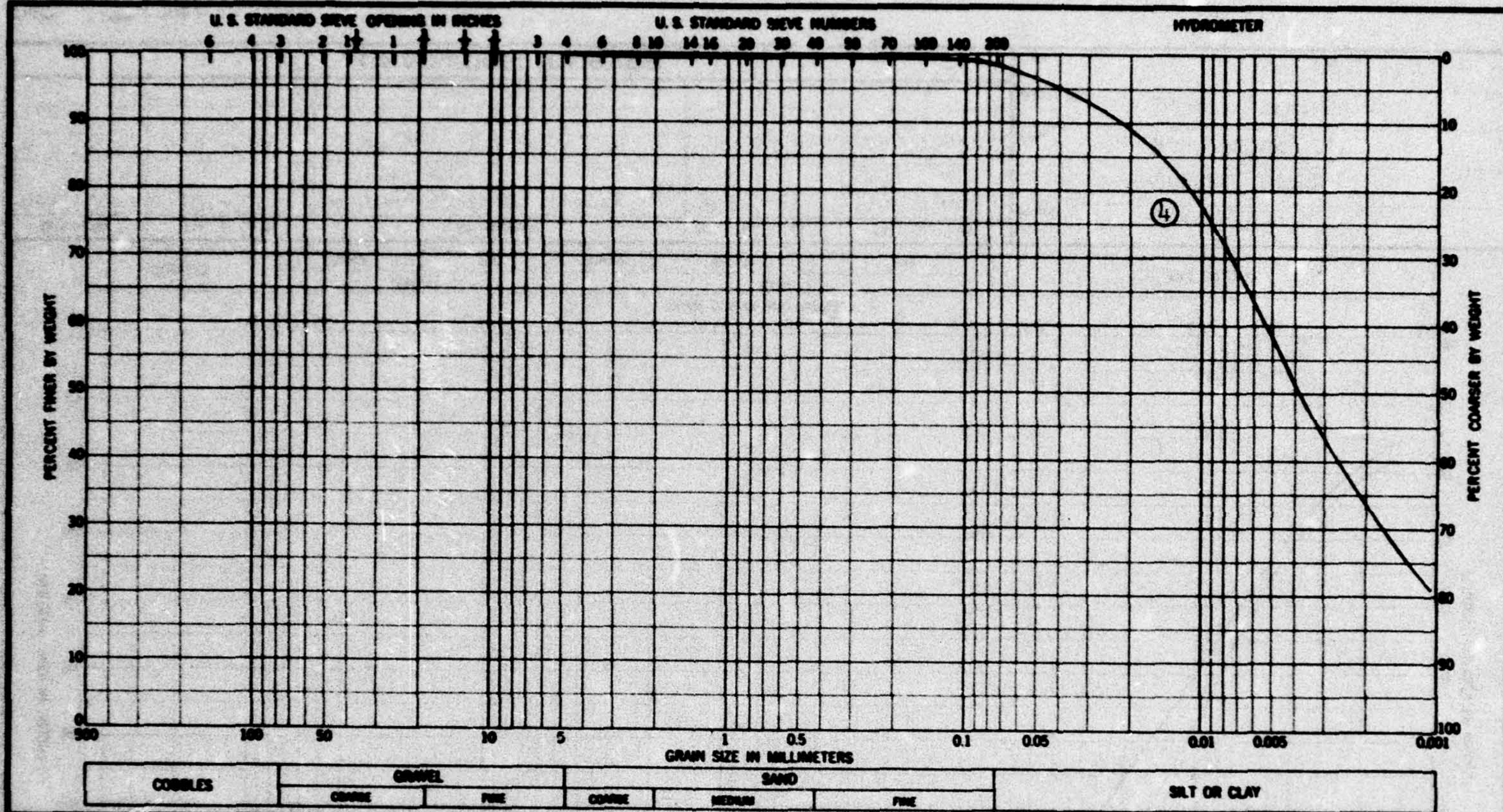

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
B-3	6.5'-8.5'	Gray, Clayey Silt MH	53.4	61	31	30
B-4	9.0'-11.0'	Brownish Gray, Clayey Silt ML	50.9	49	32	17

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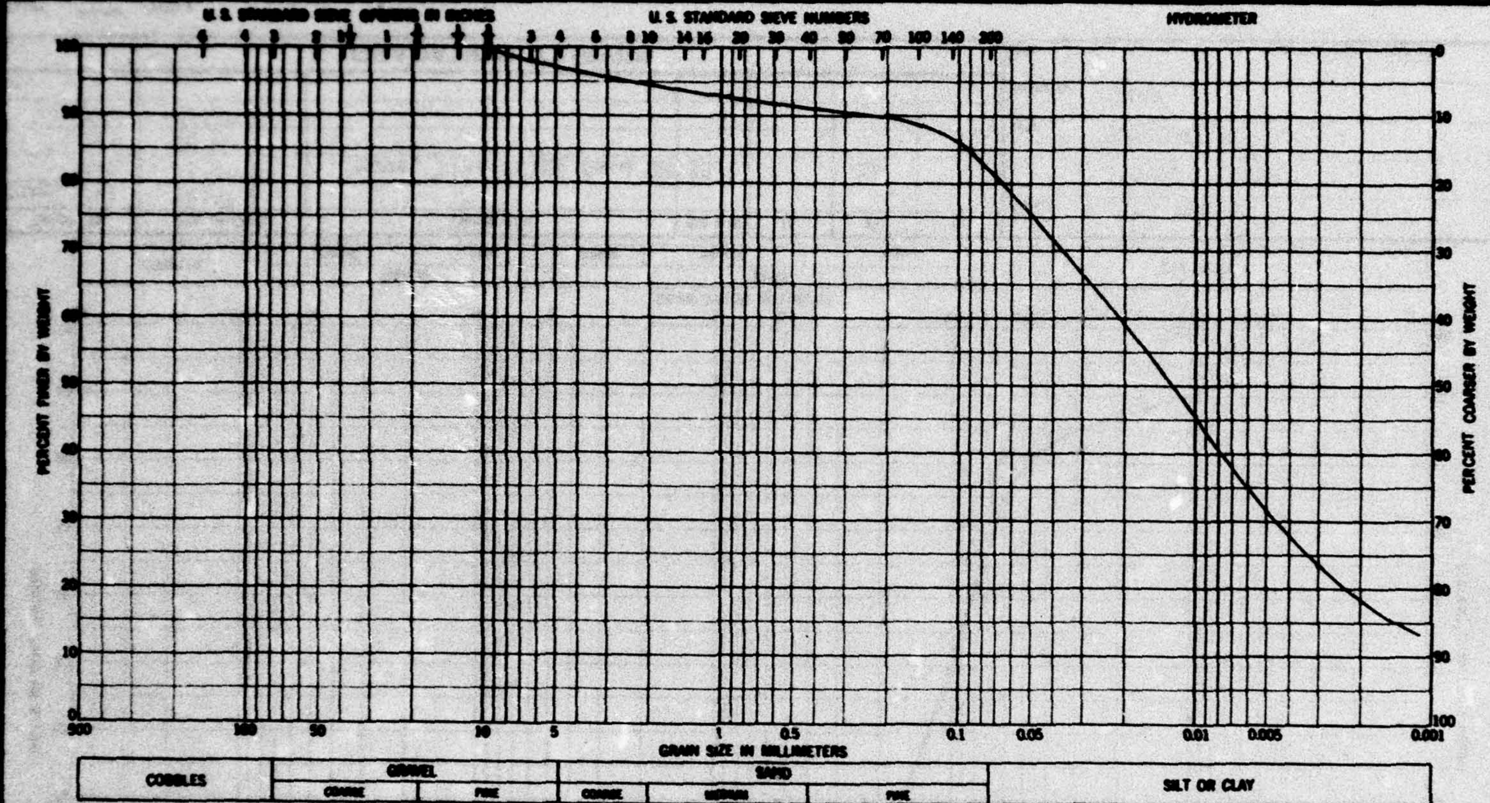

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
B-5(Bot)	11.6'-13.6'	Brownish gray, Sandy, Clayey Silt MH	52.2	58	31	27

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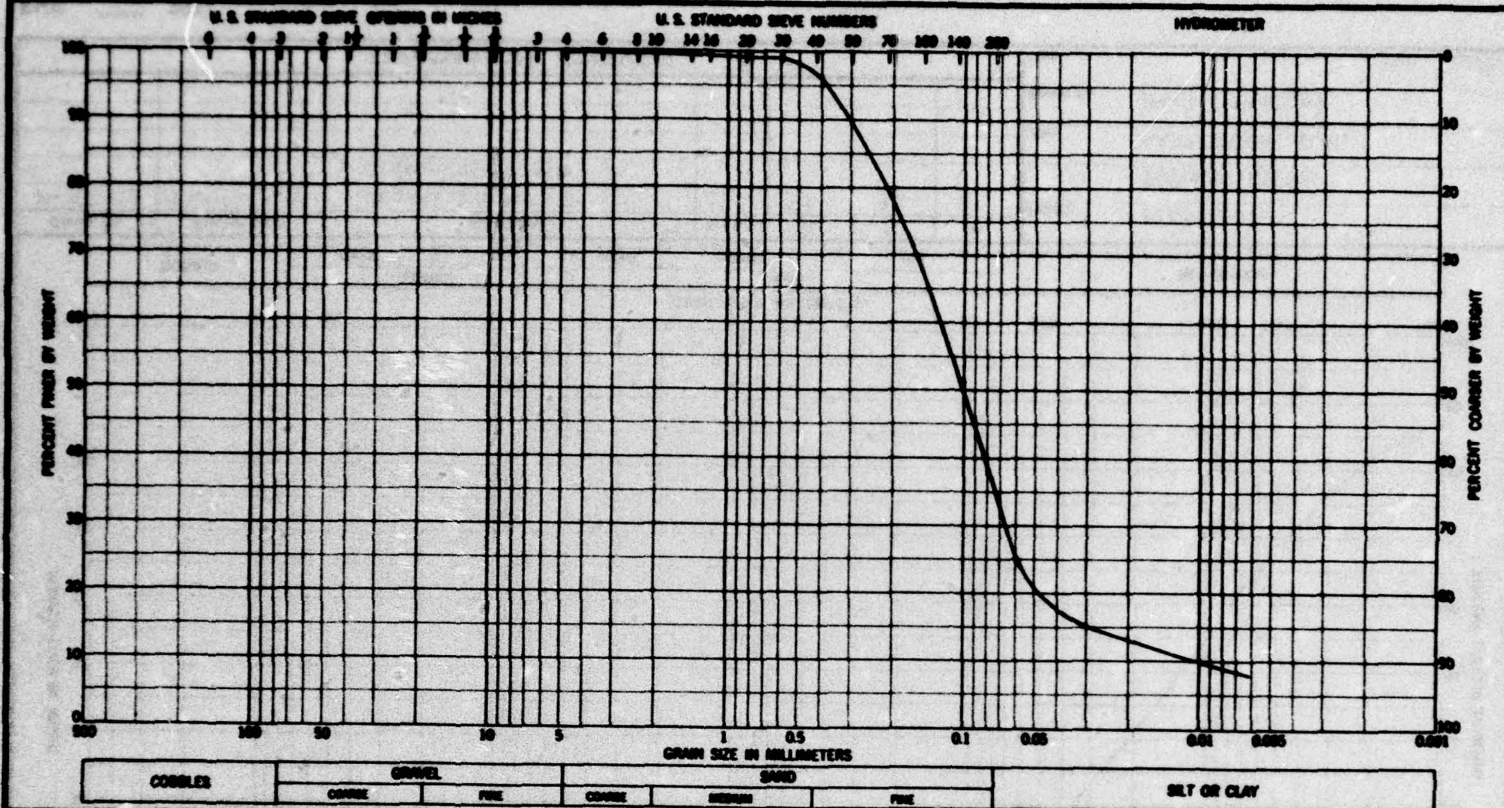

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
Comp. J-1	14'6"					
J-2	16'6"	Brown, Fine Silty Sand SM	35.1		NP	
J-3	18'6"					
J-4	21'6"					

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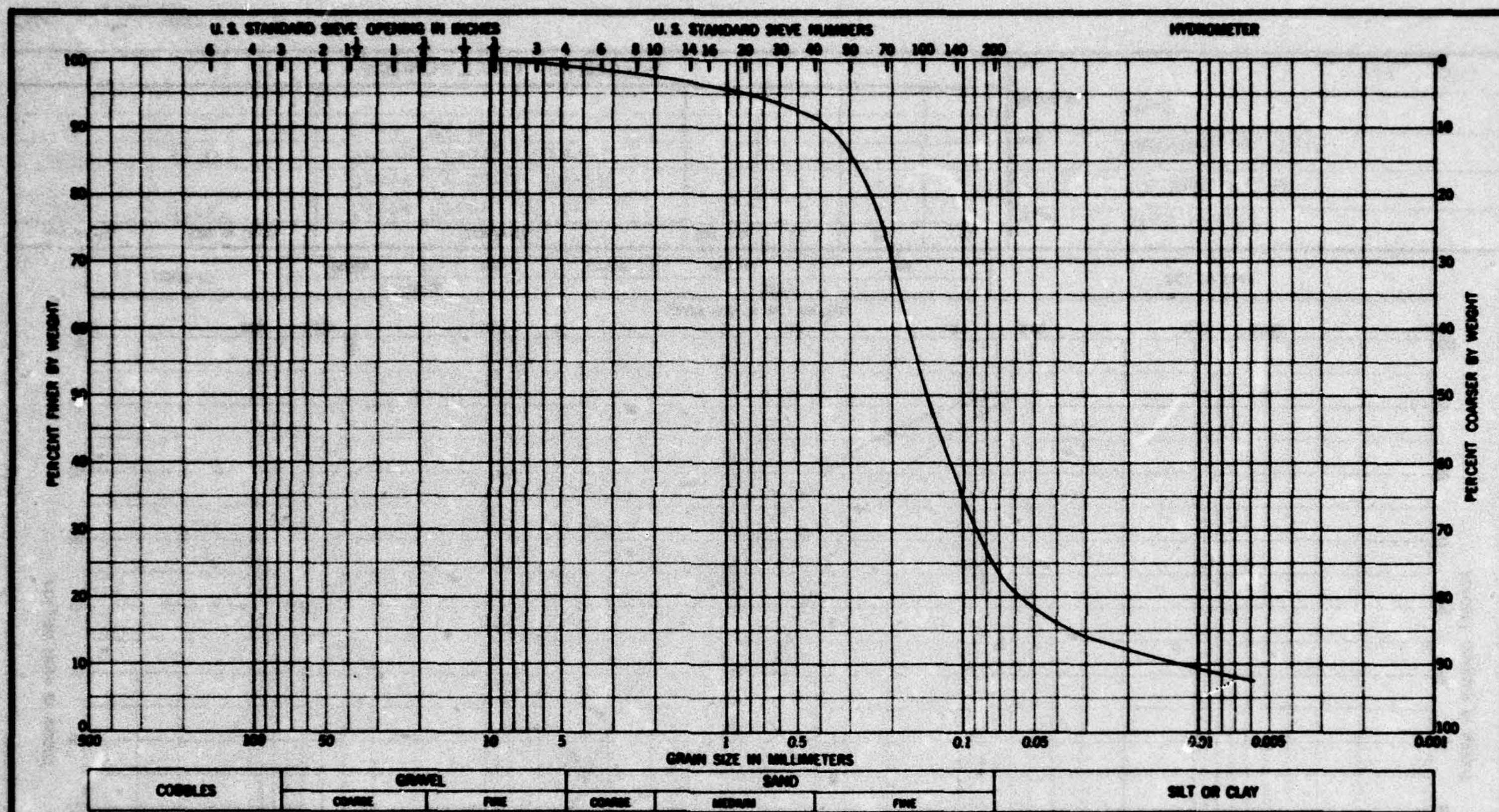

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
J-5	24'0"	Brown, Silty Sand SM	25.3	-	-	-

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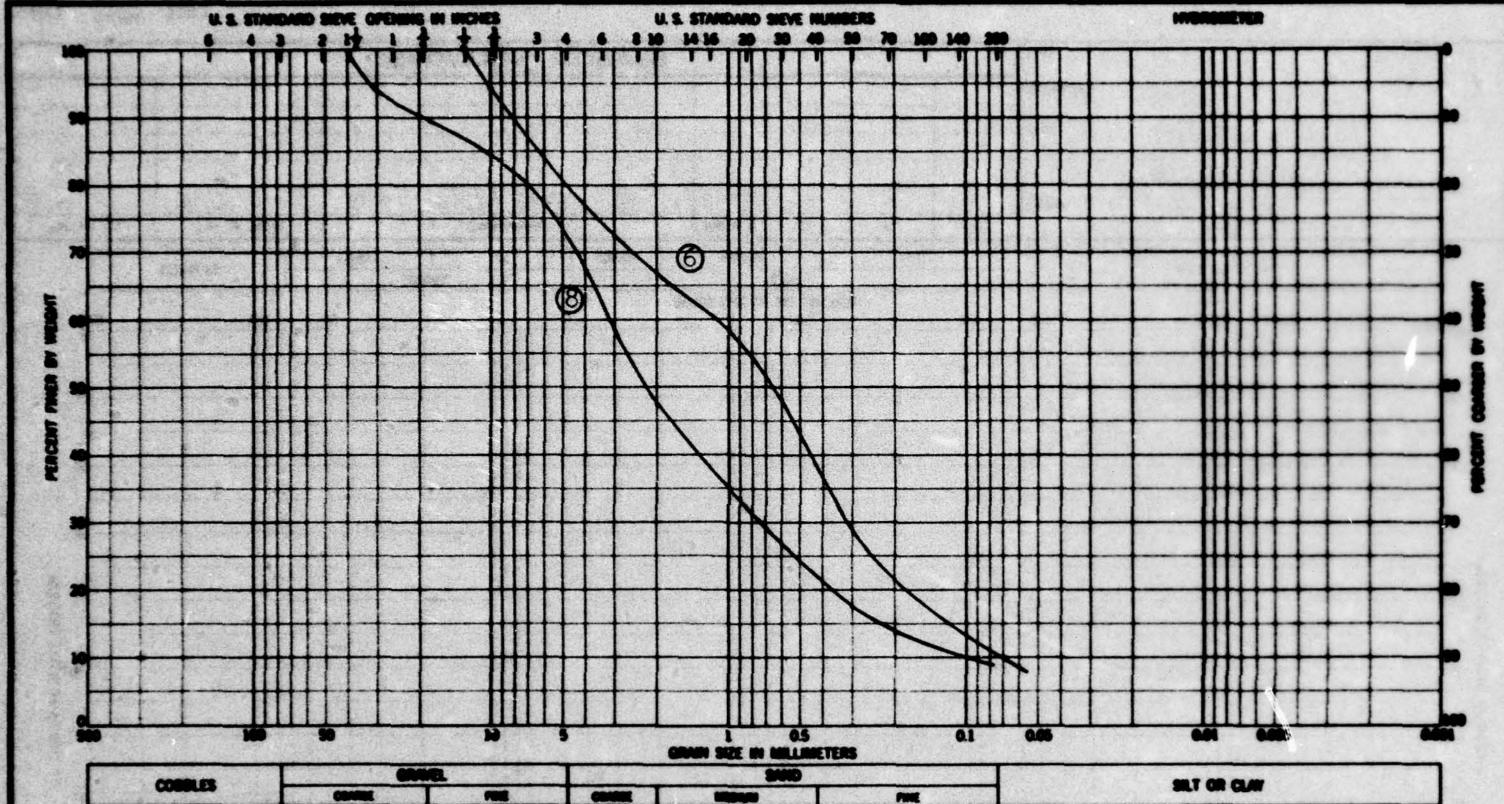

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
J-6	27'6"	Light Brown, Silty, Gravelly Sand SW-SM	13.0	-	-	-
			-	-	-	-
J-8	31'0"	Brown, Silty, Gravelly Sand SW-SM				

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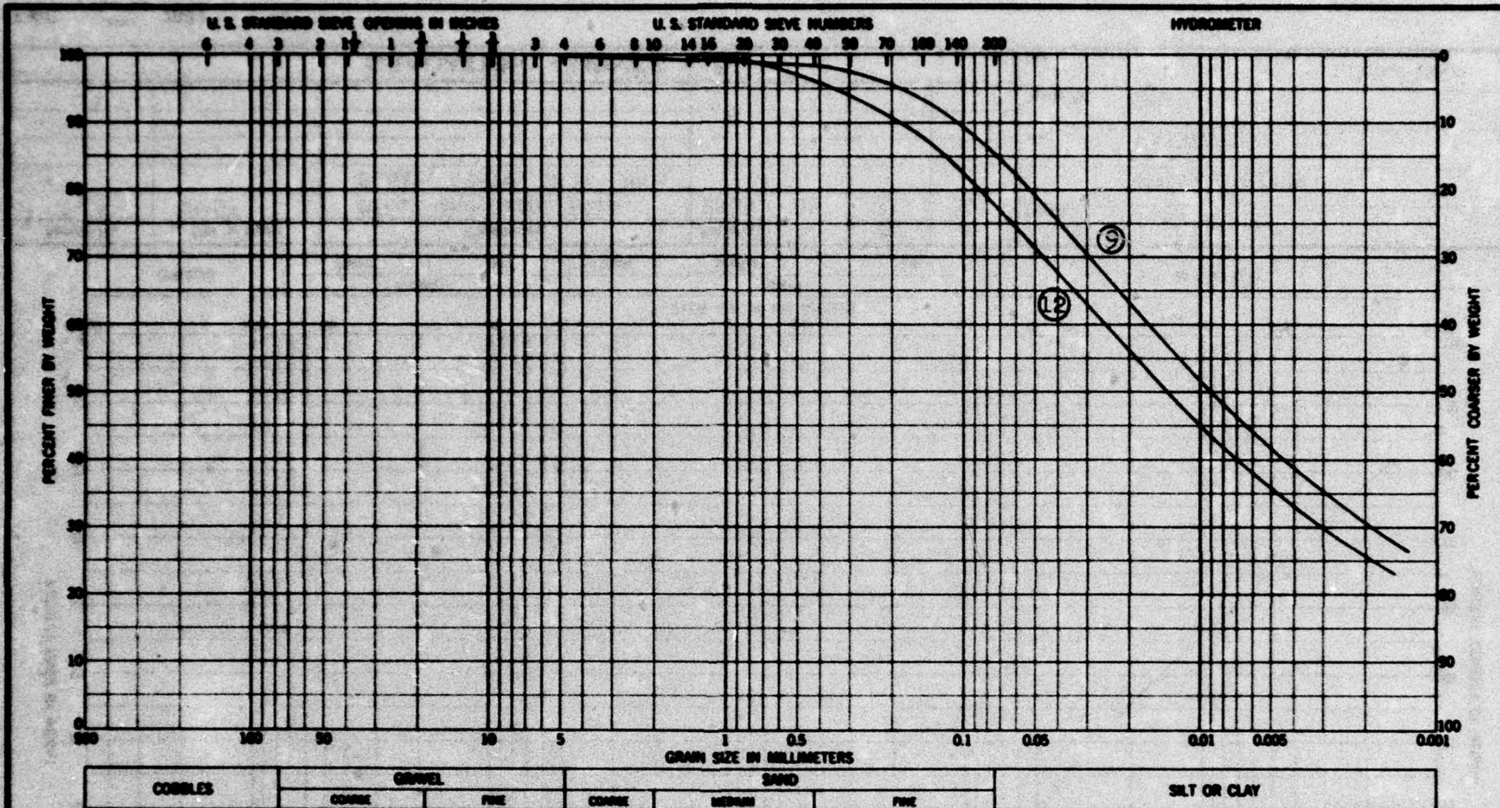

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
J-9	34'0"	Brown, Firm, Sandy Clayey Silt MH	32.3	57	34	23
J-12	40'0"	Reddish Brown and Gray, Firm, Sandy, Clayey Silt MH	32.7	61	33	28

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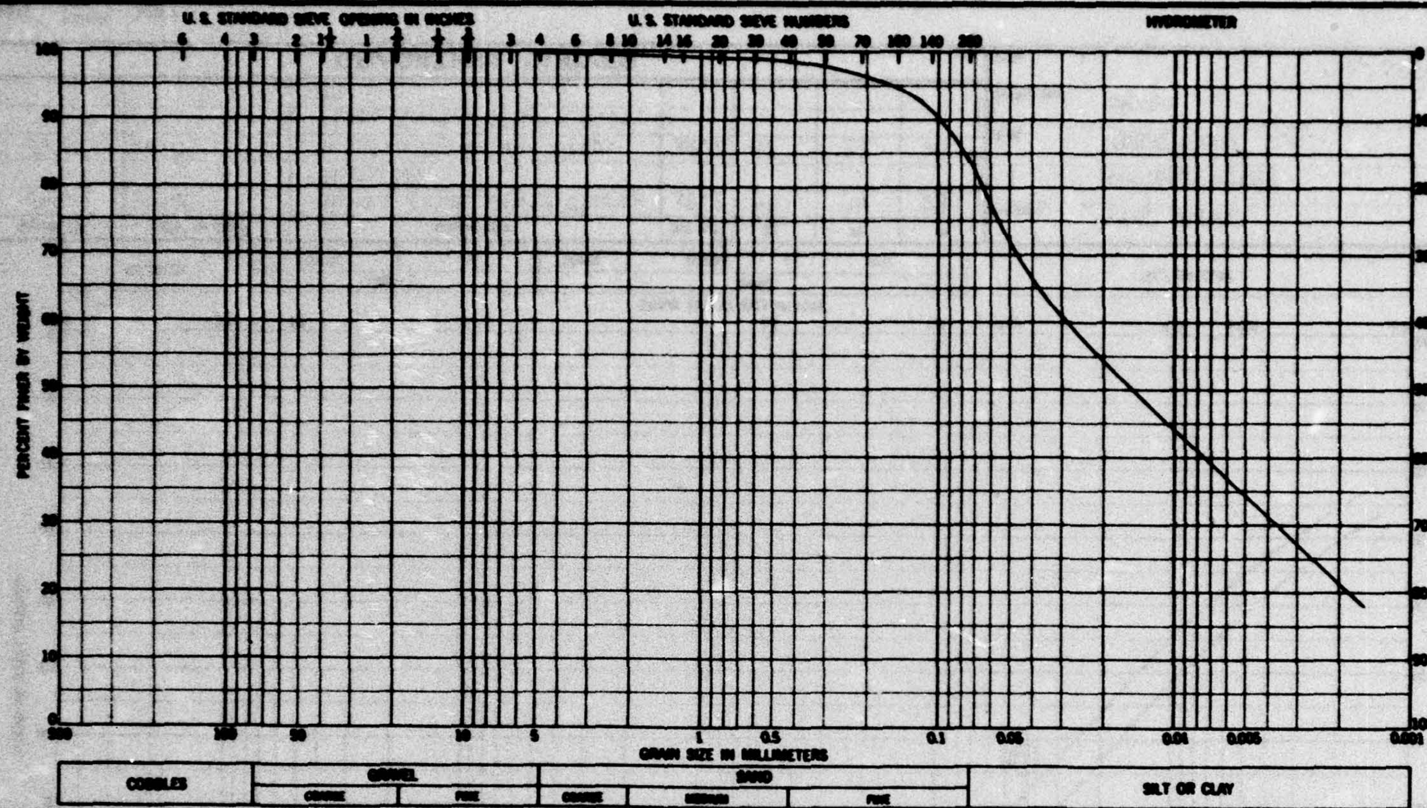

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
J-15	48'6"	Brown and Gray, Firm, Sandy, Clayey Silt MH	25.3	63	33	30

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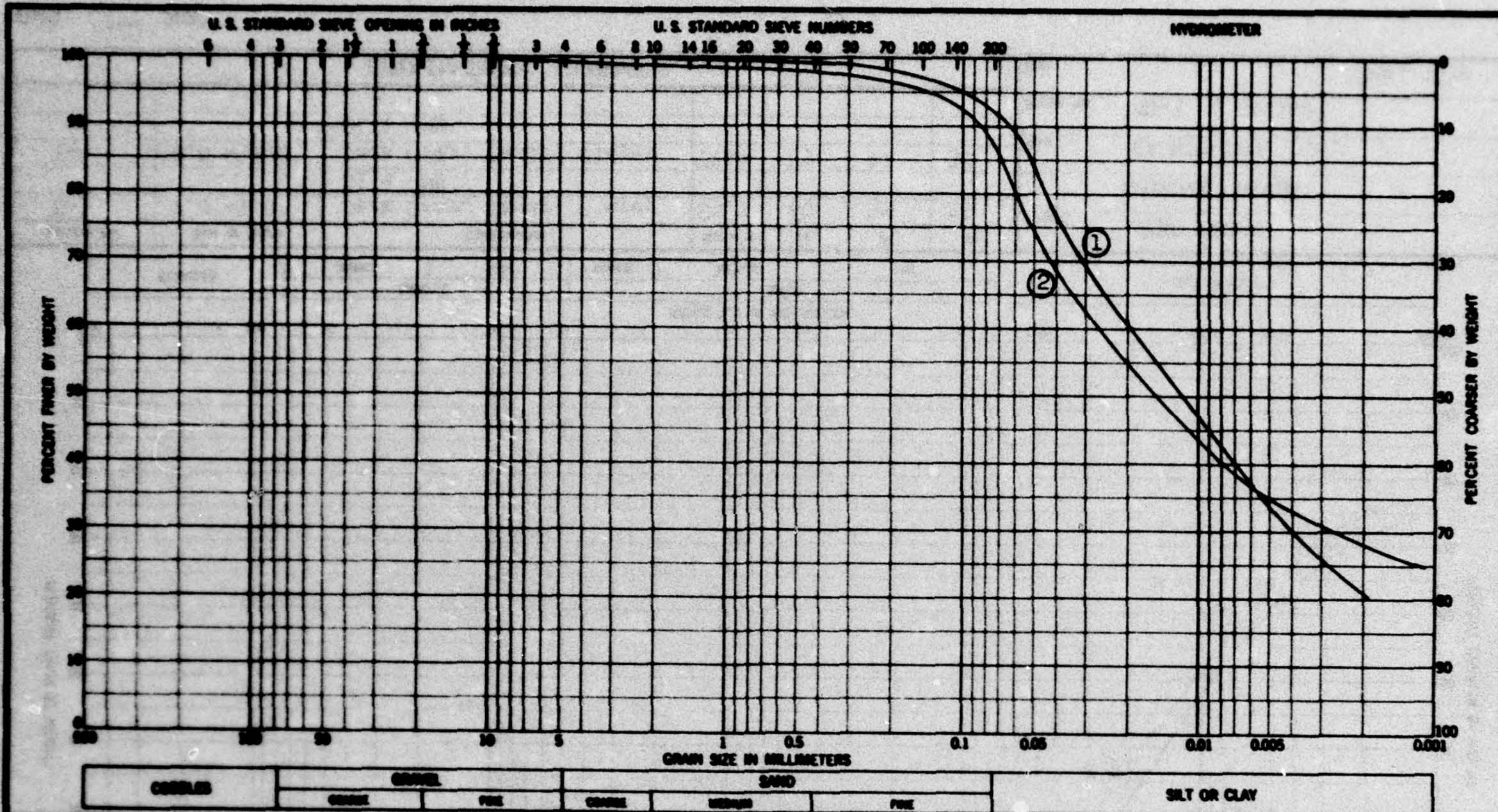

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
B-1	1.0'-3.0'	Dark Gray, Sandy, Clayey	85.1	84	40	44
		Silt MH	74.6	89	37	52
B-2	4.0'-6.0'	Dark Gray, Sandy, Clayey				
		Silt MH				

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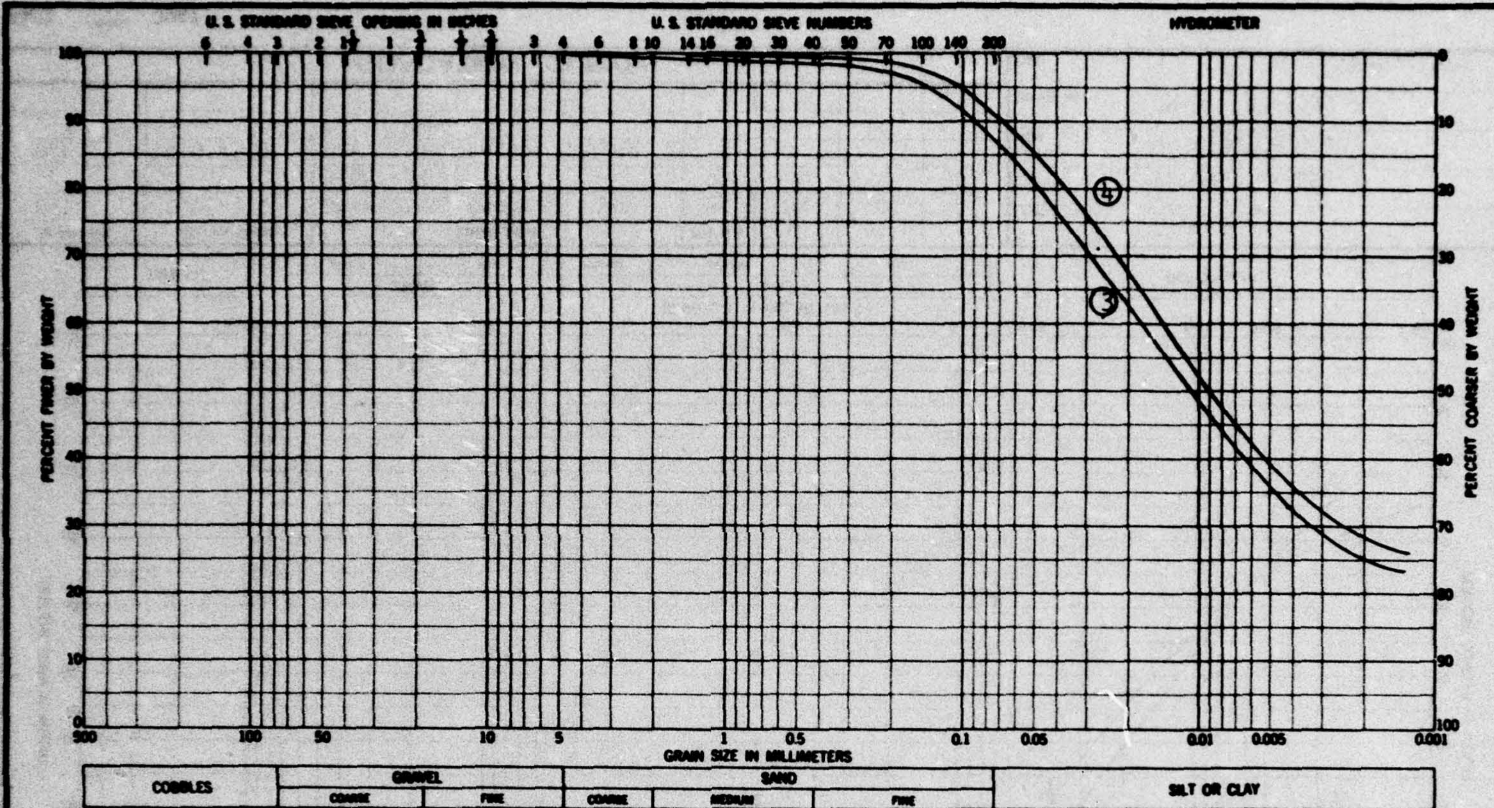

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
B-3	7.0'-9.0'	Dark Gray, Sandy, Clayey Silt MH	69.7	60	35	25
B-4	10.0'-12.0'	Dark Gray, Sandy, Clayey Silt MH	77.4	79	41	38

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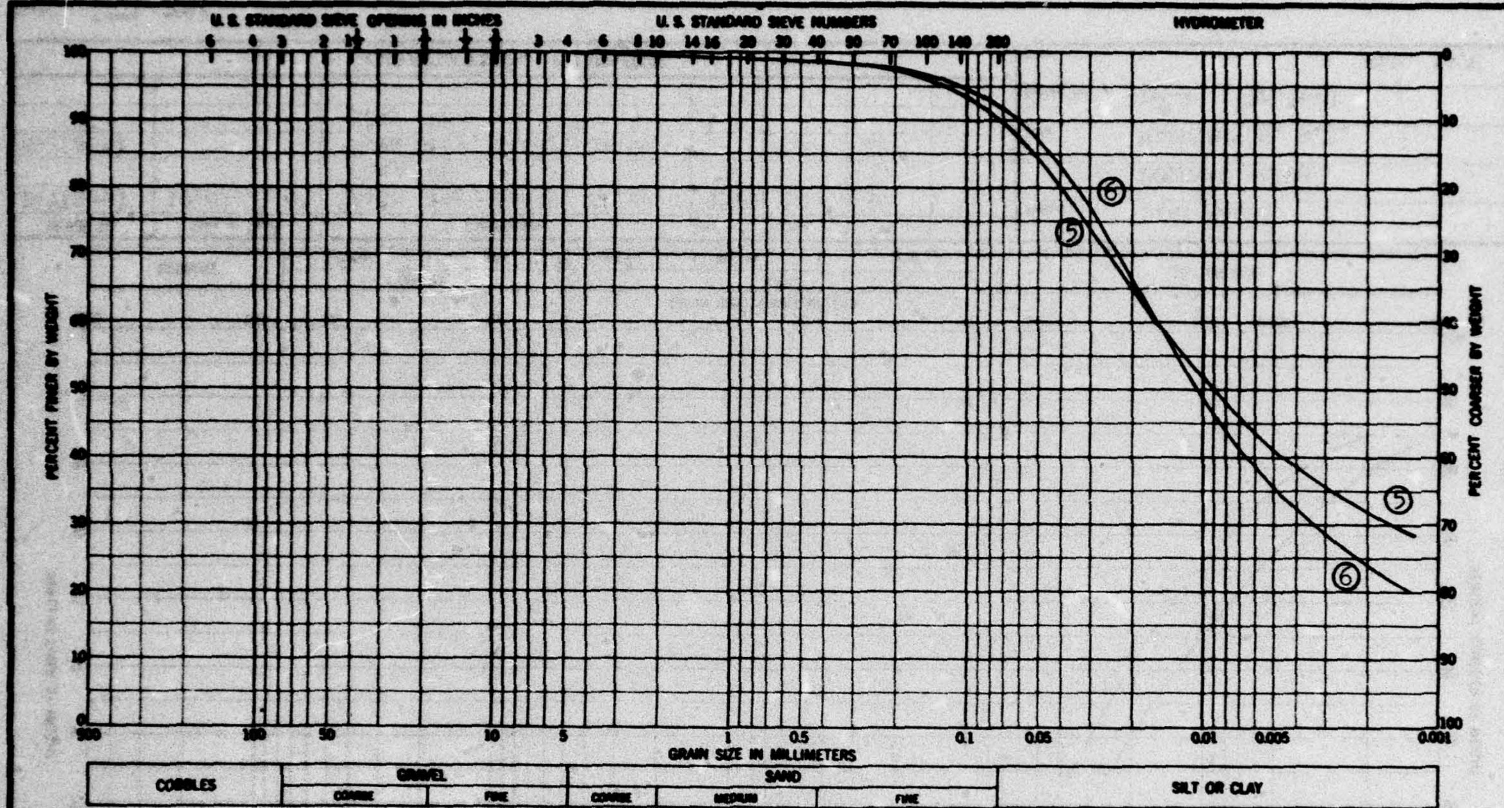

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
B-5	13.0'-15.0'	Dark Gray, Sandy, Clayey Silt MH	92.1	99	44	55
B-6	16.0'-18.0'	Dark Gray, Sandy, Clayey Silt MH	53.1	65	34	31

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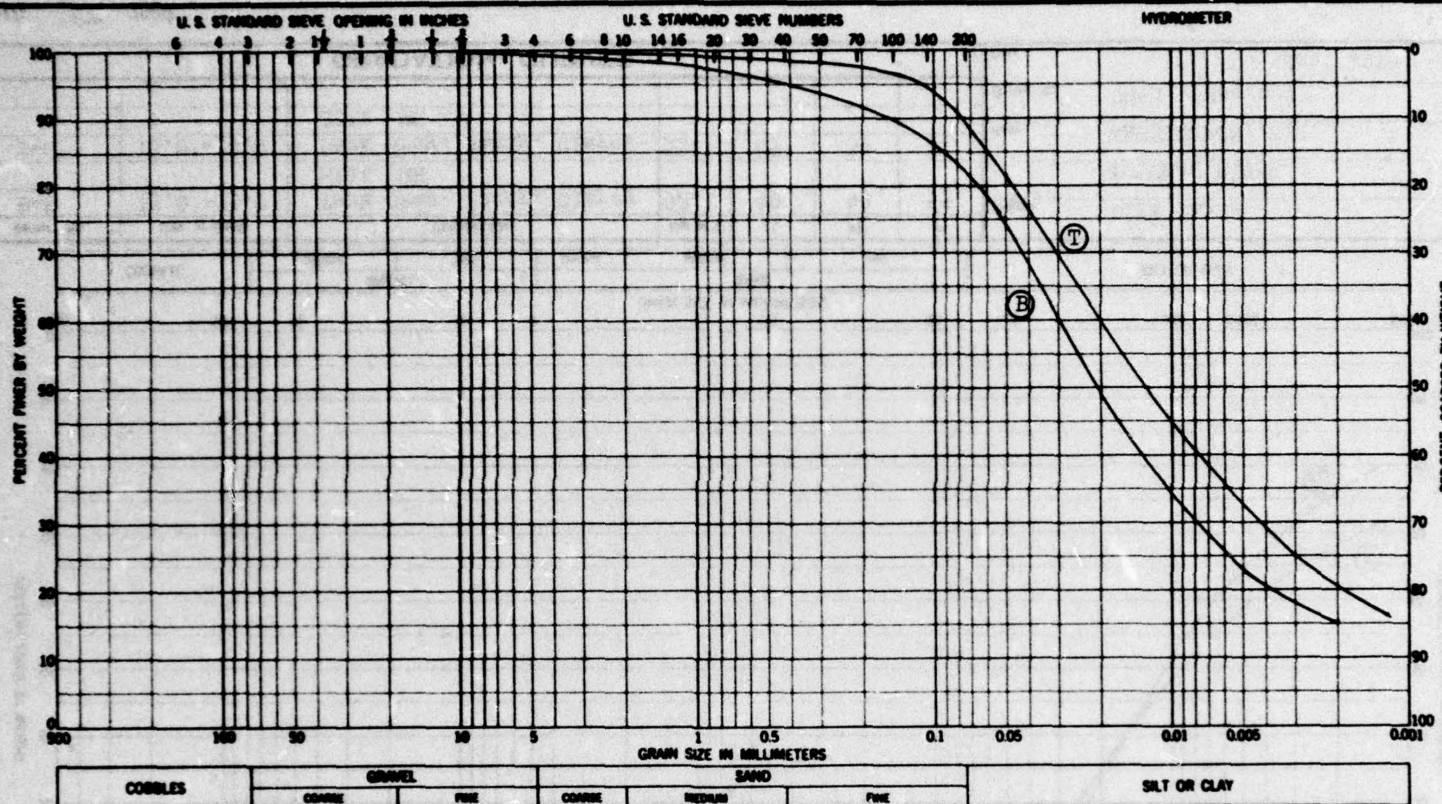

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
B-7(Top)	19.0'-21.0'	Dark Gray, Sandy, Silty Clay CH	55.9	80	36	44
B-7(Bot)		Dark Gray, Sandy, Silty Clay CH	-	67	32	35

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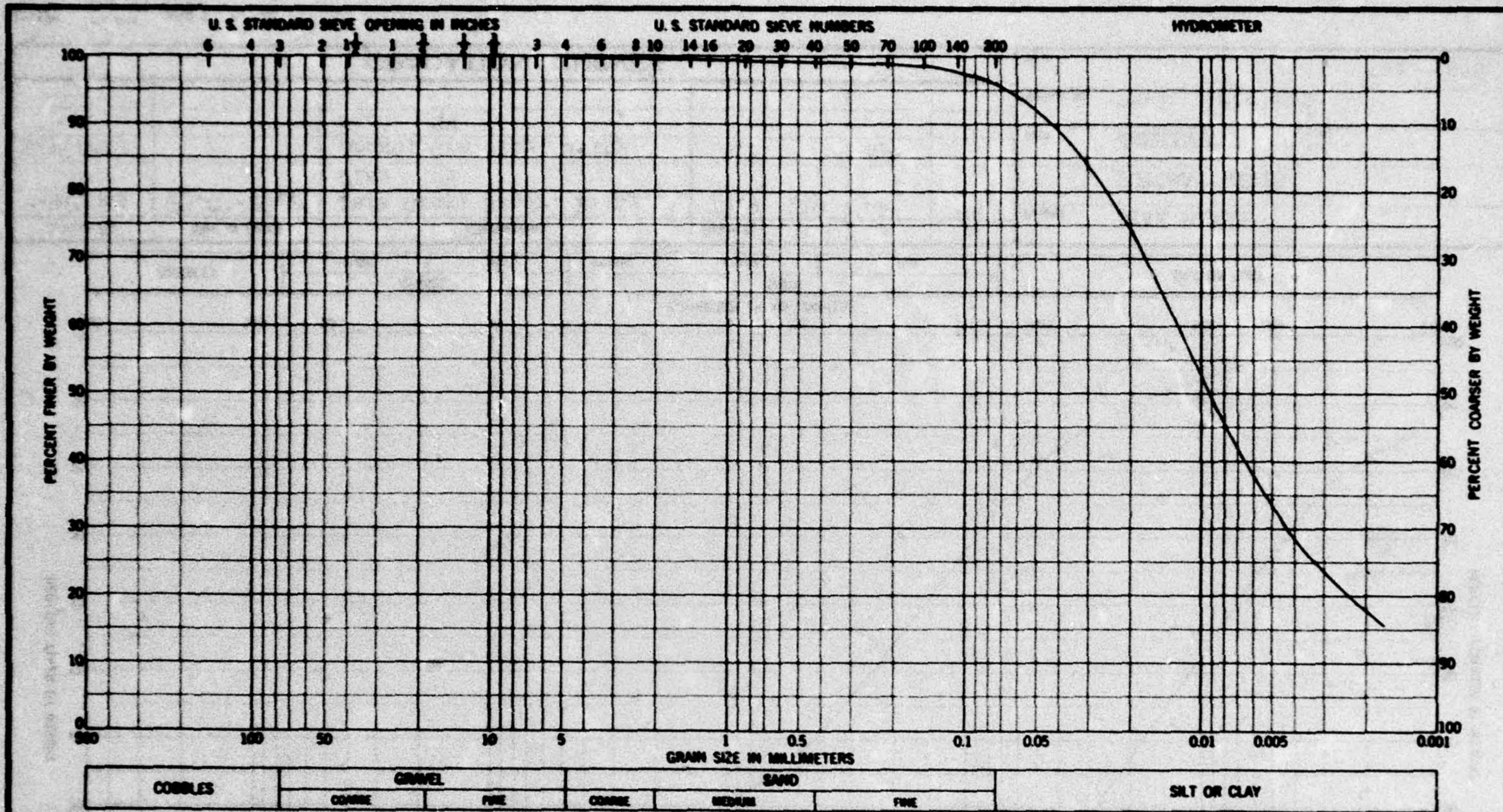

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
B-8	22.0'-24.0'	Gray, Silty, Clay CH	53.2	62	30	32

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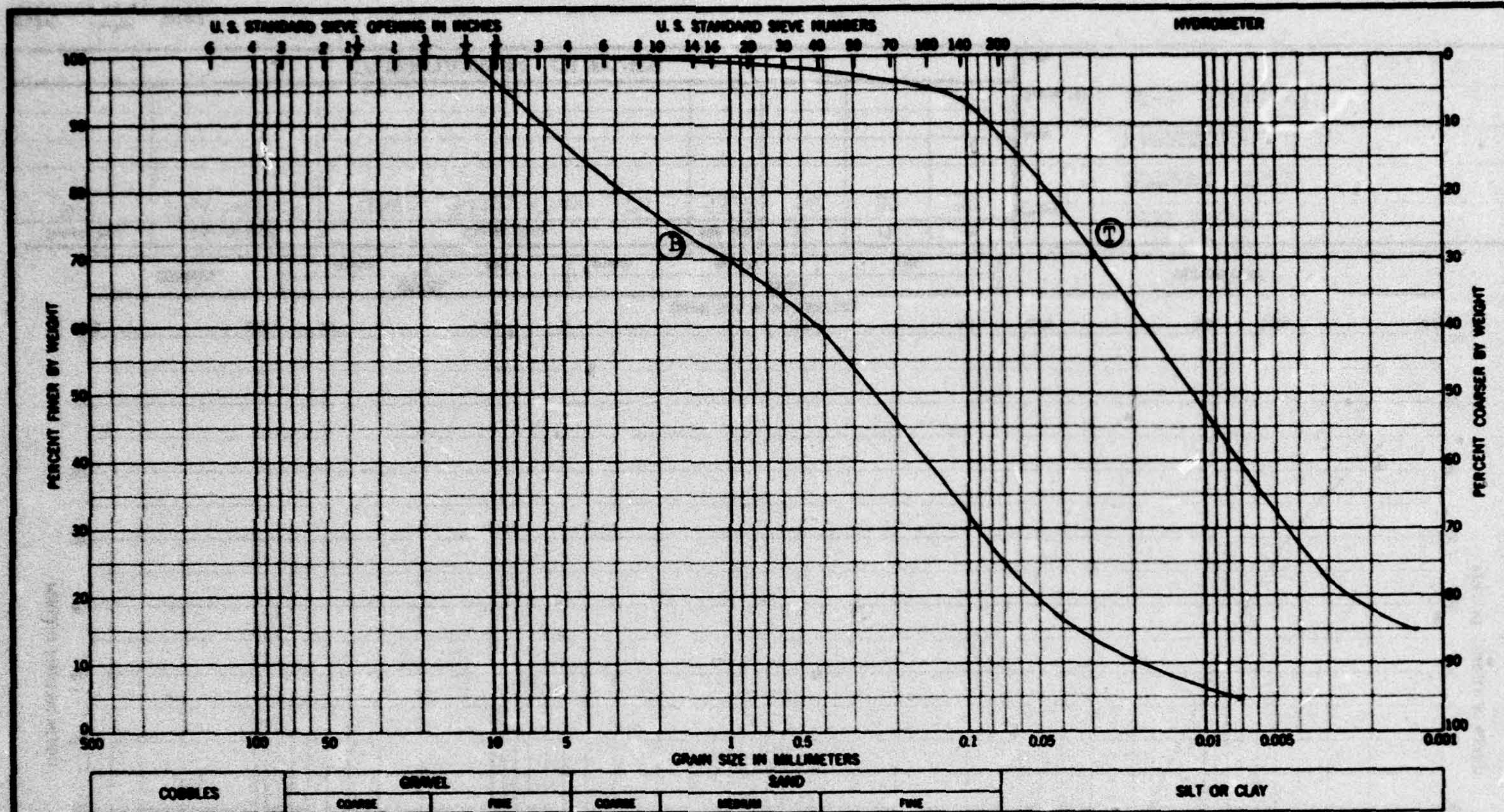

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
B-9(Top)	25.0'-26.7'	Dark Gray, Sandy, Silty, Clay CH	78.9	119	44	75
B-9(Bot)		Brown, Gravelly, Silty Sand SM	28.8		NP	

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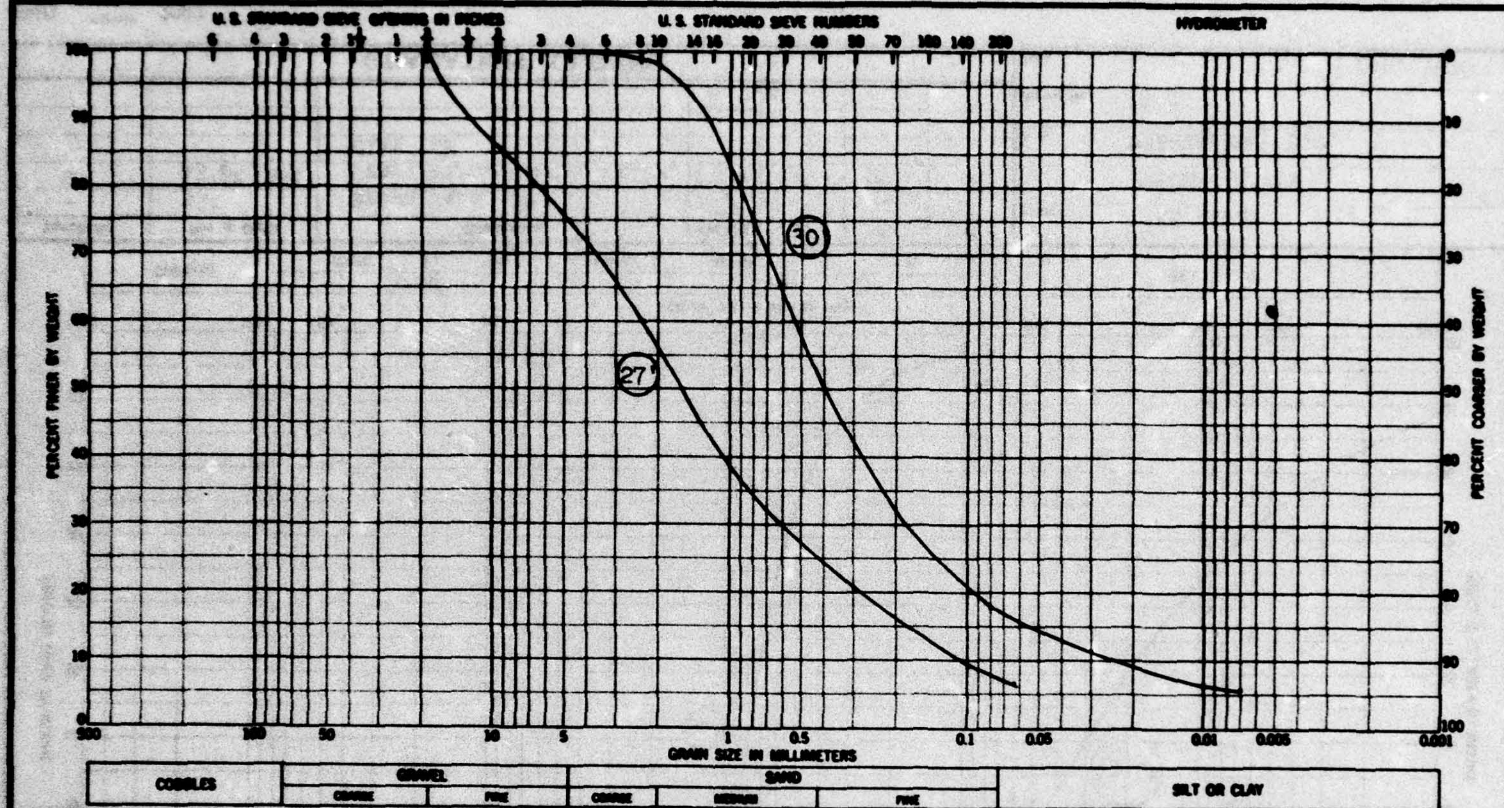

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
-	27'	Brown, Silty, Gravelly, Sand SW-SM	13.2	-	-	-
-	30'	Dark Gray Silty Sand SM	30.2	-	-	-

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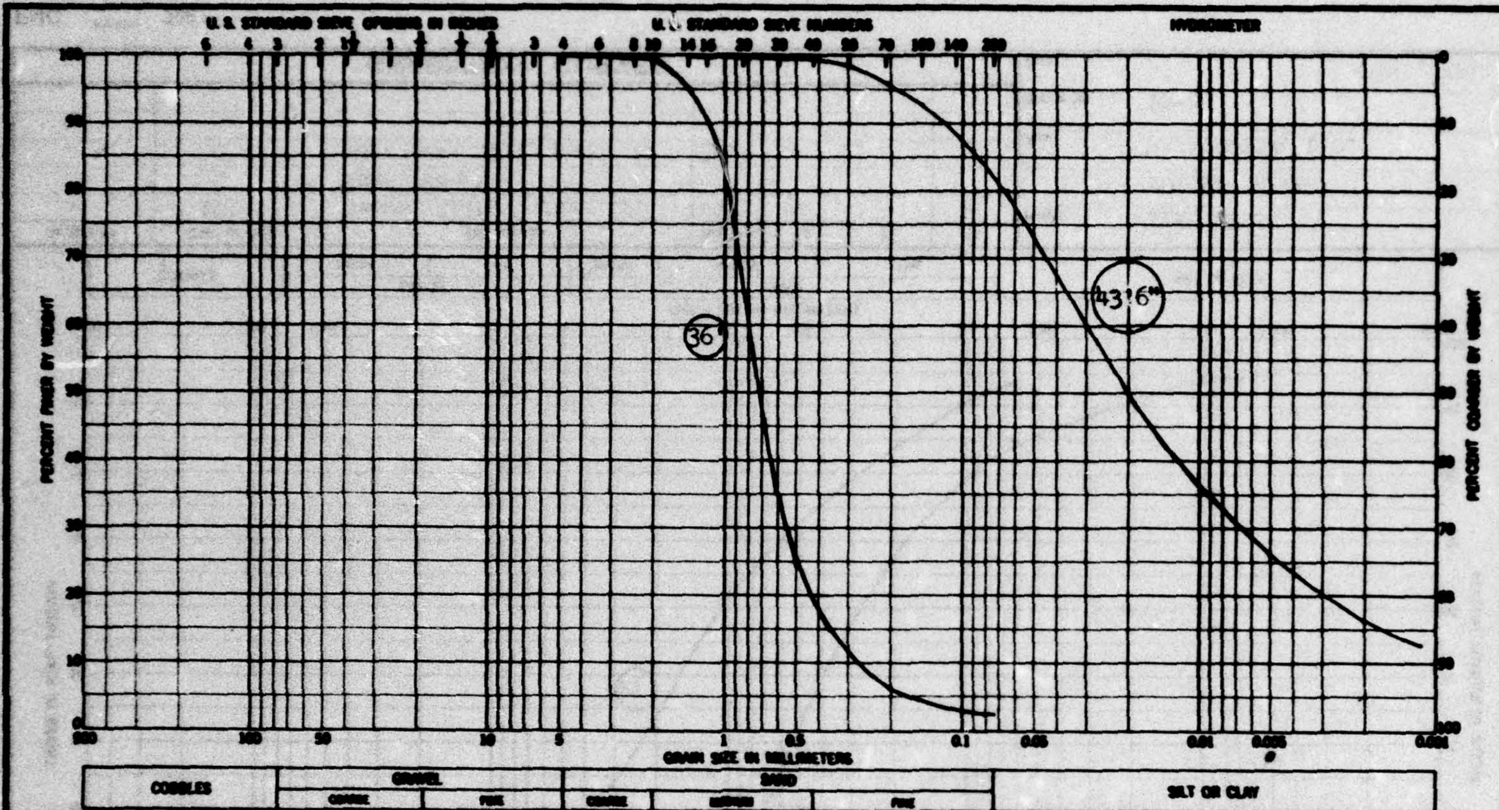

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
—	36'	Brown Sand SP	15.5	-	-	-
—	43'6" (Bot)	Gray, Firm, Sandy, Silty, Clay CH	23.9	56	27	29

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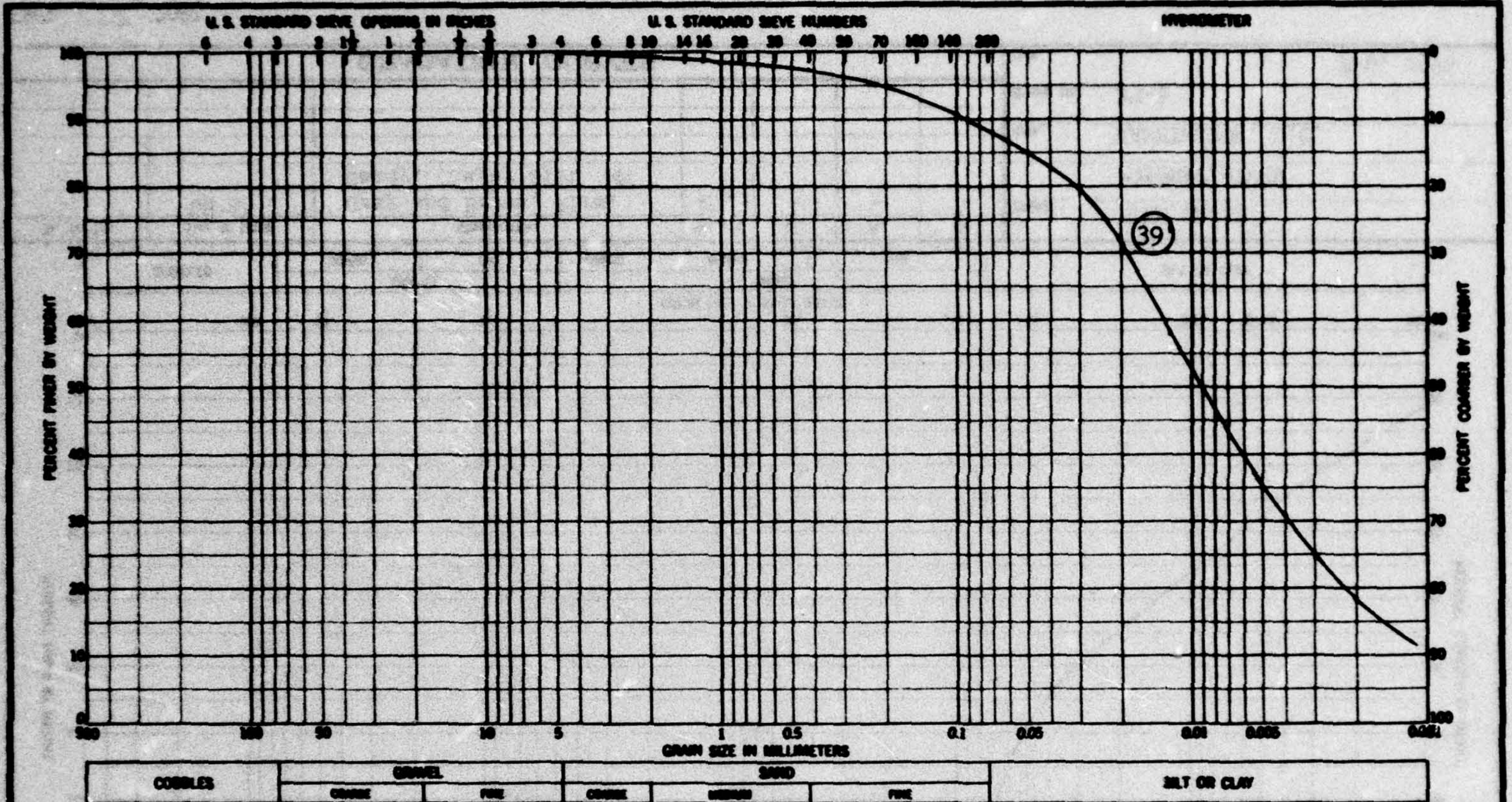

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
-	39'	Brown and Gray, Firm, Sandy, Clayey Silt MH	28.5	59	33	26

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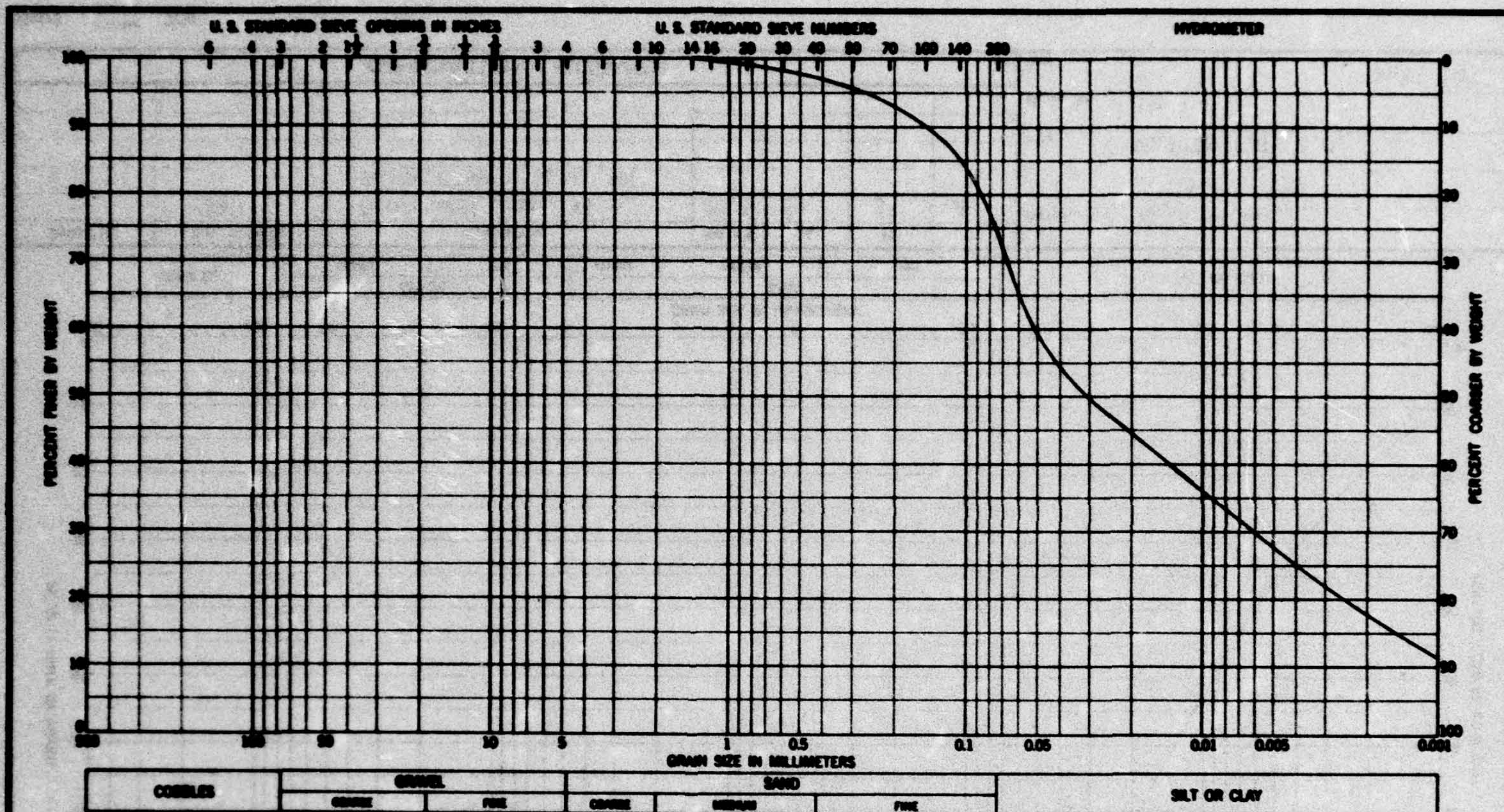

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
-	48'6"	Gray and Brown, Firm, Sandy, Clayey Silt MH	25.3	-	-	-

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Feasibility study for Dyke Marsh demonstration area, Potomac River, Virginia, by Michael R. Palermo and Timothy W. Zeigler. Vicksburg, U. S. Army Engineer Waterways Experiment Station, 1976.

1 v. (various pagings) illus. 27 cm. (U. S. Waterways Experiment Station. Technical report D-76-6)

Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C., under DMRP Work Unit 4A17.

Includes bibliography.

1. Dredged material. 2. Dyke Marsh, Va. 3. Marshes. 4. Potomac River. I. Zeigler, Timothy W., joint author. II. U. S. Army. Corps of Engineers. (Series: U. S. Waterways Experiment Station, Vicksburg, Miss. Technical report D-76-6)

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